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ABSTRACT

During the period 1984-1986, over 30 teachers from the Yorkshire (England) region have worked in collaboration with the Children's Learning in Science Project (CLIS) developing and testing teaching schemes in the areas of energy, particle theory, and plant nutrition. The project is based upon the constructivist approach to teaching. This document was developed by a group of teachers and focuses on the teaching of plant nutrition. Plant nutrition was addressed as a topic in this project because it was felt that students would gain an understanding of plant physiology, ecosystem, recycling of matter, and the interdependence of living things. The guide contains plans and pupil worksheets for six lessons organized under three broad topics: (1) probing and testing pupils' ideas; (2) presenting and exploring school science ideas; and (3) application and review of ideas. (TW)

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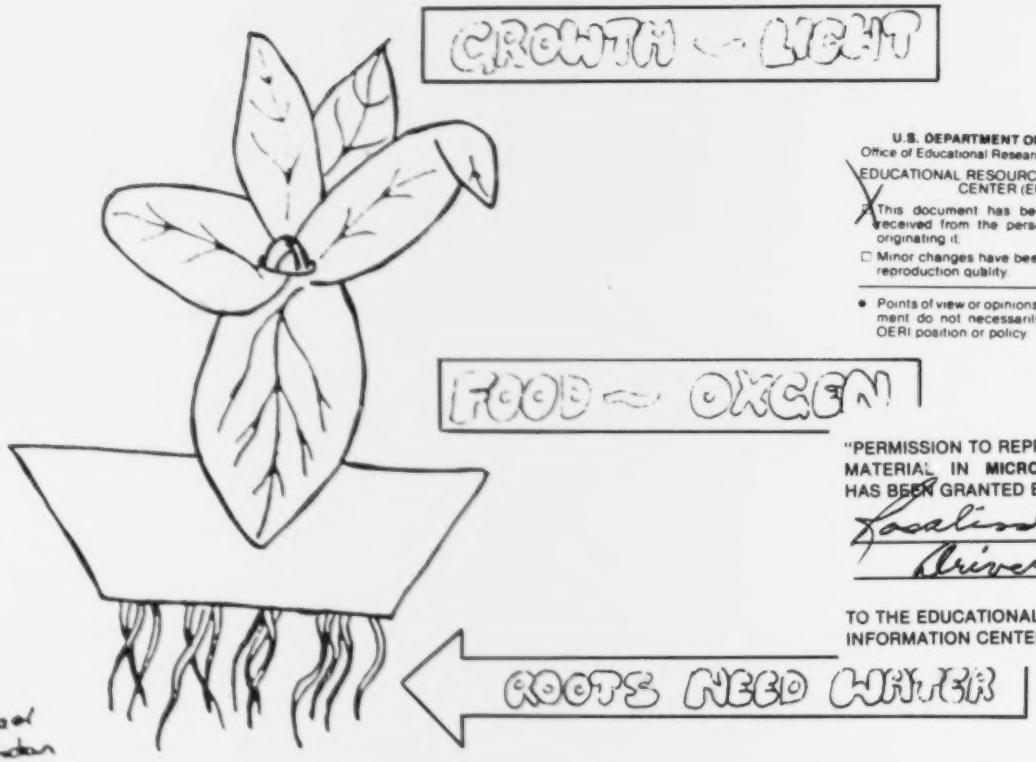

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APPROACHES TO TEACHING PLANT NUTRITION

SE 048 645

S|S C|R A research project funded by the Department of Education and Science and undertaken in collaboration with the Secondary Science Curriculum Review

Centre for Studies in Science and Mathematics Education, The University of Leeds, Leeds LS2 9JT

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Children's Learning in Science Project

Approaches to Teaching Plant Nutrition

These materials were produced by the Plant Nutrition Working Group of the Children's Learning in Science Project

June 1987

Centre for Studies in Science and Mathematics Education
University of Leeds
Leeds LS2 9JT

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The pupil material in this package may be copied for classroom use.

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These teaching materials have been developed and trialled by a group of science teachers working in collaboration with the Children's Learning in Science Project from September 1984 to July 1986. The people involved in their production were:

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The Children's Learning in Science Project was funded throughout this phase of its work (1984-1986) by the Department of Education and Science and the School Curriculum Development Committee through the Secondary Science Curriculum Review.

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Finally, we would like to thank members of the Steering Committee, Steve Gater and Michael Madden for their helpful comments on the draft, and the Assessment of Performance Unit for permission to use some of their materials.

Preface

This scheme for the teaching of plant nutrition was written by a group of teachers working with the Children's Learning in Science Project.

We consider plant nutrition to be an essential part of all pupils' education, to enable them to develop an understanding of plant physiology, ecosystems, recycling of matter and interdependence of living things.

The scheme includes the use of teaching strategies that are intended to help pupils understand difficult scientific concepts. It is our intention that readers should use this example of a teaching scheme as a basis from which to build materials suited to their own use. We would welcome feedback from teachers who have used the scheme either as published, or in modified form.

The materials were designed for use with mixed ability classes of pupils in the third year of secondary schools (age 13-14 years).

1 The teaching of plant nutrition: some issues

1.1 The place of plant nutrition in the school curriculum

In many schools, pupils of twelve or thirteen are taught photosynthesis at a preliminary level. For older pupils, the process of photosynthesis forms a basis for the development of an understanding of food chains and energy flow, recycling of matter and ecosystems, and the interdependence of organisms. These concepts have occupied an increasingly large proportion of science curricula in recent years and form a substantial part of the content of current GCSE syllabuses. For this reason, it is important that pupils should develop an understanding of plant nutrition in order to support their grasp of other biological ideas which are central to the understanding of the relationships between themselves, other organisms and the environment.

In terms of general education it is important that young people appreciate the role that green plants play in the biosphere; that plants are ultimately a source of food and that green plants are responsible for maintaining the balance of gases in the earth's atmosphere.

We recognise, however, that this topic is considered difficult by both pupils and teachers, and the purpose of this section is to describe some learning and teaching issues associated with plant nutrition.

1.2 Plant nutrition: the science teacher's perspective

The following synopsis illustrates the process of plant nutrition as it may be presented to school pupils. (It is recognised that this scientific perspective may be modified by teachers according to the needs of their classes.)

"Light energy, absorbed by chlorophyll, combines the hydrogen from water, with carbon dioxide, to form sugar. Oxygen is also produced in this reaction, and may be given out as a by-product. This aspect of plant nutrition is called photosynthesis.

The sugar produced may be used as a source of energy for the plant, it may be stored, or it may be used to aid the manufacture of other substances required by the plant. Stored sugar is usually first converted to some other substance such as lipid or starch. Plants need other food substances to grow successfully. These may require certain minerals from the soil to be incorporated into their structure. Examples of this include nitrates in the manufacture of protein and phosphates in the manufacture of genetic material."

This summary would probably be accepted by most science teachers as an appropriate overview of photosynthesis. Differences of opinion may occur, however, on the meaning teachers ascribe to the word 'food' in the course of their lessons. Some would restrict the meaning to those substances which plants manufacture, others may include substances such as minerals which plants take in from their environment. This latter meaning of 'food', as something which is taken in from the environment, corresponds closely to the ideas which pupils usually bring to their learning. Within this scheme account is taken of these various meanings.

1.3 Plant nutrition: the pupils' perspective

Pupils are likely to have developed ideas about plant growth and plant feeding, as well as more general ideas about food, before they are introduced to scientific ideas in school. This everyday knowledge about the natural world and about plants in particular, may be reinforced by the language of advertisements for fertilisers, gardening programmes, and discussions with family and peers. This everyday knowledge often differs from, or conflicts with the ideas pupils meet in school.

The following overview presents the kinds of ideas that pupils bring to their science lessons, and the conceptual difficulties which may be encountered while learning about plant nutrition. The overview draws on investigations of pupils' ideas undertaken by this project, and by researchers in other countries (1). (It is interesting to note common features in the results of these studies, despite differences in language, culture and school curricula.)

Pupils' ideas about plant feeding

Most pupils at secondary school level appreciate that water and light are needed for the survival and healthy growth of plants. However, they are also aware that plants take in substances from the ground through their roots, and tend to identify these substances as food (after all, animals' food is material taken in through their mouths). If the word 'food' is used during the topic, then this is likely to be the association pupils have for it, rather than the 'energy store' notion which some teachers may intend. The idea that plants 'make food' could also be understood by pupils in a way the teacher might not expect; some pupils have described this as being similar to Mum making dinner!

Briefly, the ideas about plant feeding which pupils tend to bring to their lessons from their everyday knowledge are:

- plants obtain their food from the environment in the same way as animals, i.e. ready-made
- plants take in food through their roots
- food for plants may be seen as anything that they take in from outside, e.g. air, water, fertilisers, sunlight
- plants need food to grow, be healthy.

The following paragraphs consider some of the conceptual difficulties which can arise from these ideas during teaching.

Pupils' ideas about gases and plants

Pupils are usually introduced to the processes of gas exchange when learning about breathing in animals. They are taught that during respiration, oxygen is taken in by the organism and carbon dioxide, the by-product, is given out. When they are introduced to the process of photosynthesis in which carbon dioxide is taken in and oxygen is the by-product, they tend to see the two processes as 'opposite'; one taking place in animals, the other in plants. In general there is confusion about gas exchange in plants, with pupils often not appreciating that respiration and photosynthesis may be occurring at the same time. Examples of pupils' ideas include:

- plants do not use air, they do not breathe
- plants use air in the opposite way to animals
- plants respire only in the dark
- photosynthesis is a sort of respiration
- plants give out oxygen all the time.

Pupils' ideas about the role of chlorophyll

Chlorophyll and photosynthesis are terms that pupils may be encountering for the first time, and confusion may arise because one of these words describes a substance and one describes a process. Some pupils have described plants as 'making photosynthesis'. The role chlorophyll plays in the process is often not clearly understood, and pupils may suggest that chlorophyll:

- attracts sunlight
- is used for making the leaves green
- is for protection, survival.

Other conceptual difficulties

Pupils have difficulty in understanding how matter may change from one phase to another. When studying plant nutrition, pupils are expected to learn that carbon dioxide (gas) and water (liquid) are combined to form carbohydrate (solid), and that this carbohydrate product may be interchanged between soluble and insoluble form, depending on the circumstances.

Few chemical reactions encountered by school pupils involve the synthesis, or building up, of complex compounds until late in their school careers. Pupils have reported difficulty in understanding how carbon dioxide and water can be joined to each other. Even the meaning of the term 'synthesis' can be confusing. Some pupils associate it with the notion of copying because musical synthesisers store and copy musical notes.

Many pupils tend to think of energy as being 'used up' whenever a change occurs. It is difficult, therefore, for them to envisage plants 'storing energy' as a consequence of photosynthesis. Furthermore, pupils tend to associate energy with moving things and thus have difficulty appreciating the role of energy in the life of a plant. Some pupils may confuse matter and energy, seeing the sunlight itself being converted into plant material.

Conceptual barriers encountered by pupils in practical work

To illustrate the process of photosynthesis, many school text books describe experiments that investigate the presence of starch in plants that have been deprived of certain factors. In our experience, pupils have less difficulty in recognising which factors are necessary for photosynthesis than in understanding the process with which these factors are involved.

Although these experiments may be used as a vehicle for considering aspects of experimental design, we have found that they tend to hinder pupils' understanding of plant nutrition (2). There may be several reasons for this.

a) Procedures and processes

Techniques such as testing leaves for starch involve many steps and necessitate a 'recipe following' approach. Some pupils find this hard in itself since they get confused over the sequence of stages. These procedures also cause pupils to be distracted from the purpose of the investigation and to lose sight of the underlying principles. Many of the traditional photosynthesis experiments are used as a method of teaching scientific processes such as the use of controls. This may detract from an understanding of the concepts behind the practical work.

b) Relating observation to theory

If pupils lack the theoretical understanding needed to make sense of an activity then they may focus their attention on something other than that intended by the teacher. (For example, pupils frequently mistake air bubbles for cells when using microscopes, and in this situation are unlikely to be able to relate their observations to an understanding of osmosis if the teacher expects them to 'see' plasmolysed cells.) If the pupil makes the intended observation (such as the centre of a variegated Pelargonium leaf becomes darker when iodine is added, in the traditional starch test) they do not always succeed in linking it to the underlying theory (in this case, starch is only present in the cells of the leaf that previously contained chlorophyll), but may offer alternative interpretations i.e. they construct alternative meanings.

c) Starch - sugar relationship

If pupils are taught that sugars are the products of photosynthesis, they may not understand the relationship between starch and sugar, or why the starch test is used.

1.4 About this package

In this section, we have outlined the rationale for adopting a different approach to the teaching of plant nutrition: an approach which acknowledges pupils' prior ideas and which is designed to encourage them to change and develop. Further information about the scheme, including its aims and how it was developed, is given in Section 2. The teaching approach being advocated is based on contemporary perspectives on learning and teaching. These perspectives and practical advice on putting them into practice are outlined in Section 3.

The scheme itself is presented in Section 4. This section includes notes on each lesson and pupil materials. The approach to the topic which we suggest is open-ended by nature. This means that in practice, teachers need to use the feedback from one lesson in choosing the issues to focus on in the next. Initially, this may require teachers to think on their feet, and in order to provide some guidance which may be helpful we have included notes from the

trialling of the scheme. These illustrate what happened in the lessons and the ideas pupils generated in response to the tasks set. We have noted that there are common patterns in the activities of different classes, and we hope therefore, that this information will help someone who is teaching the scheme for the first time to be better prepared for the issues which may arise.

The final section gives some reflections on the scheme from both pupils and teachers. We also invite those using the scheme to send us their comments and reactions.

2 The teaching scheme: rationale and overview

2.1 Aims of the scheme

The teaching materials have been designed to encourage the development by pupils of the following ideas about plant nutrition:

a) Food is material that can be used by organisms as a source of energy.

b) Plants, like animals, need food to provide energy for various metabolic reactions and also to provide material for growth and repair. Green plants are able to make their own food by a process called photosynthesis. This is different from animals which take in food from the outside. In fact, since plants make their own food and animals cannot, animals are dependant on plants for food.

c) Green plants depend on the sun as a source of energy. The light energy absorbed by chlorophyll, a green pigment found mainly inside leaf cells, is transformed into chemical energy. This chemical energy is then used to combine two simple substances, carbon dioxide from the air and water from the soil, into more complex sugars. Oxygen is produced in this process. The sugars which are produced may be used immediately or converted and stored as starch.

d) In addition to sugars, the plant requires other foods, such as proteins and fats, for healthy growth. These can be produced from sugars and may require other chemicals for their production. These extra chemicals are usually absorbed as mineral salts from the soil.

The materials are based on a view of learning as an active process in which individuals make sense of their experiences in terms of existing ideas. Thus the ideas which pupils bring to their science lessons are crucially important in determining what they learn from their classroom experiences.

In the course of the scheme pupils are given the opportunity to become aware of their own ideas and how their ideas change. By recognising their own learning, we have found that pupils become aware of what they have still to learn and this increases their motivation.

Through testing out their own ideas pupils also develop a greater appreciation of the issues involved in testing a theory. They come to realise that several, possibly conflicting, theories may be used to explain a given phenomenon and that these may be equally valid depending on circumstance.

Finally, we hope that teachers will become increasingly aware of the ideas and aspirations of their pupils through the use of the teaching approach described here, and that they will then be in a better position to relate their short term and long term teaching aims to these expectations.

2.2 Scheme in outline

The teaching scheme consists of three main sections and is shown in outline in figure 2.1. It is designed for use in comprehensive schools with 13-14 year olds, and to take about six double periods (though more time could profitably be spent on it).

It was developed by a group of twelve secondary science teachers from Yorkshire, a biology education tutor and an educational researcher. The development and trialling by the group took place between September 1984 and July 1986.

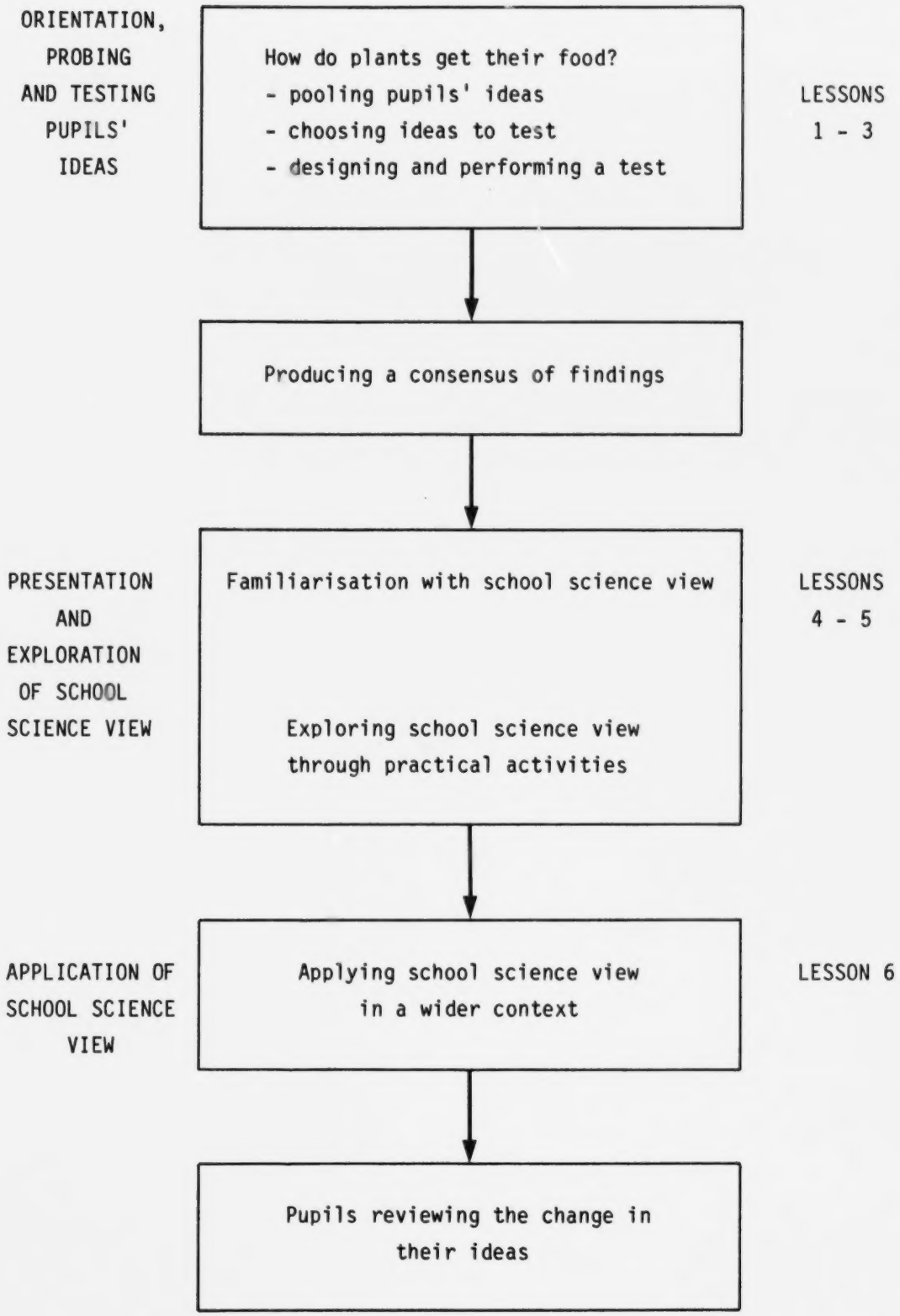

ORIENTATION, PROBING AND TESTING PUPILS' IDEAS
How do plants get their food?
- pooling pupils' ideas
- choosing ideas to test
- designing and performing a test
LESSONS 1 - 3
Producing a consensus of findings
PRESENTATION AND EXPLORATION OF SCHOOL SCIENCE VIEW
Familiarisation with school science view
Exploring school science view through practical activities
LESSONS 4 - 5
APPLICATION OF SCHOOL SCIENCE VIEW
Applying school science view in a wider context
LESSON 6
Pupils reviewing the change in their ideas

Figure 2.1 Outline of the plant nutrition teaching scheme

In many schools, plant nutrition is taught using a sequence of carefully structured experiments aimed at identifying the various factors involved in photosynthesis. The topic is thus also used as a vehicle for the development of experimental skills, such as the use of controls. However, as we have already discussed, even with careful teaching, pupils experience conceptual difficulties in understanding key ideas about plant nutrition. One reason for this is that they bring well established ideas to the lessons and thus may construct unintended meanings from the activities presented.

In this scheme time is given at the beginning of the teaching sequence for pupils to share and explore their ideas about 'how plants get their food'. This includes an opportunity to devise and carry out their own practical investigations and to review their own results as a group. This section of work may be quite 'divergent' in character in that pupils may investigate a wide range of ideas. It provides an opportunity for pupils to design and carry out their own investigations and to learn about the issues involved in experimentation (the need for clear observable criteria for a dependent variable, the need for controls etc.). It also enables pupils to clarify their own ideas about food and plants through considering each others' experimental results. However, this experimental work is not designed to be a vehicle for developing an understanding of the scientific view.

The second section of the scheme focusses on the school science view of plant nutrition. Pupils are given an outline explanation of plant nutrition on information sheets. They are then asked to use the ideas in the sheets to explain a range of situations or events which are presented to them. These activities are designed to illustrate a range of aspects of the biological processes involved in photosynthesis (light absorption, gas exchange, sugar production etc.). Explaining these activities enables pupils to explore and understand better the school science view.

The final section of work gives opportunities for pupils to apply the school science view in wider contexts. A range of types of activity from practical projects to drama are suggested here. At the end pupils are encouraged to review the way their ideas have changed during the sequence of lessons.

In overview, therefore, the scheme gives pupils an opportunity to explore their own ideas both through discussion and experiment. It then presents the school science view giving pupils opportunities to construct this view for themselves and relate it to a range of relevant phenomena.

2.3 Links with other science topics

Learning biological topics often involves drawing on and making links with a wide range of scientific ideas. Plant nutrition is no exception. Whilst we do not suggest that pupils need to 'know' a set of ideas as an essential pre-requisite to their learning, it may aid their construction of meaning if they can draw on and make links with the following ideas.

a) Living things: The difference between living and non-living, and between animal and plant.

b) Animal nutrition: Food provides energy and component molecules for growth. There are many different foods which may be classified chemically, each with a distinctive chemical testing technique. One type of food is carbohydrate of which starch and sugar are examples, and this contains the elements carbon, hydrogen and oxygen.

c) Energy: Living things all need energy, which is used for a variety of purposes. Light is a form of energy which can be transformed, for example, into electrical energy by a photoelectric cell, or chemical energy by a photographic emulsion.

d) Matter: Matter may exist in one of three phases. It may also be classified as an element, mixture or compound. Water is a compound of hydrogen and oxygen; carbon dioxide is a compound of carbon and oxygen.

e) Light: 'White' light is made up of a mixture of lights of different colours.

2.4 How the scheme was developed and evaluated

The teaching scheme is the result of an extended and detailed investigation by a working group of teachers and researchers. We focussed initially on the conceptual difficulties pupils tend to have in learning this topic. This involved reviewing the literature, undertaking diagnostic tests in our own classrooms and documenting pupils' work during conventional teaching of the topic. Some of our findings from this phase of work have already been reported (2).

As a result of our analysis of this preliminary work a revised teaching scheme was developed. In designing the scheme the following factors were taken into consideration:

- decisions about intended learning outcomes in terms of biological content, scientific skills and learning skills
- insights into some of the difficulties pupils encounter when learning this topic
- perspectives on the learning process
- our experiences as teachers and our knowledge of pupils, classrooms and schools.

The initial draft scheme was trialled and revised on the basis of our classroom experiences, and revisions were implemented in a further four third year classes (3).

In evaluating the scheme the perspectives of pupils, teachers and researchers have been taken into account. We wished to find out whether these materials were effective in bringing about conceptual change and also how pupils and teachers reacted to the use of the scheme. Various strategies were employed during the evaluation and these are outlined briefly below. For further details of the procedures and outcomes see (4).

1. From the pupils' perspective, we wished to know:

   - did the pupils change their ideas?
   - were they involved in the learning activities?
   - what was their attitude to this revised method of working?

   The strategies we employed in finding answers to these questions were tests that we administered before and after teaching, questionnaires to investigate pupils' reactions and the observations of a researcher in a sample of classrooms.

2. From the teachers' perspective, we wished to know:

   - how did teachers react to each of the learning activities?
   - what was the teachers' perception of their pupils' reaction to working in this way?

   We kept detailed diaries from each lesson to record our responses to these questions.

3. From the researcher's perspective we wished to know if these materials were effective in bringing about conceptual change. To find the answer to this question, the researcher drew on notes made in lessons, interview notes and material gathered in each of the strategies described above.

Teachers may be interested in the list of questions that we developed for our own self-evaluation of our lessons. They are listed below.

Are the pupils given opportunities to:

- express and exchange their own ideas?
- reflect on, compare and evaluate their own ideas and those of others?
- use their imagination in testing their ideas experimentally?
- become familiar with scientific concepts and to develop confidence in using these ideas?

Does the teacher provide:

- experiences which challenge ideas and interact with prior knowledge?
- an environment where pupils' ideas are valued and respected?
- the chance for feedback in terms of learning and reactions to lessons?

Through our involvement with the project we were given opportunities to evaluate the quality of the learning taking place in our classrooms, to identify weaknesses and to trial different approaches. We obtained feedback not only from the teacher's perspective, but also from pupils and from an observer in the lessons. At the same time we were able to reflect on research into pupils' learning and to discuss the implications of this research for our own lessons. This scheme is the product of this process.

3 Classroom teaching strategies

This section outlines some of the guidelines we used when implementing particular teaching strategies. These strategies take account of the importance of pupils' ideas in learning and also the view that learning involves actively constructing new meanings to change existing conceptions (5). In adopting this view of learning we wished to change our usual style of teaching by:

- consciously encouraging a classroom atmosphere in which all ideas were genuinely valued
- enabling pupils to become aware of their own ideas and those of their colleagues
- allowing time for pupils to develop understanding and to evaluate their learning
- enabling pupils to review their own learning.

The strategies we employed were not novel to us, but we had never previously linked them to any specific view of learning, or fitted them into an overall teaching plan.

3.1 Practical work

The practical work in this scheme is designed with a number of purposes in mind.

Some of the activities (lessons 2 and 3) give pupils the opportunity to test out their own ideas by designing and performing their own experiments. The role of the teacher in these activities is to act as adviser on practical matters. When allowing pupils to test their own ideas we found it difficult to restrain ourselves from interfering if we thought a

particular procedure was inappropriate, or if it would produce unexpected results. It is important at this stage to recognise that the pupils' hypotheses about plant feeding may differ from the scientific view. The purpose of this phase is to give them the chance to test their ideas - the teacher's role is to help them clarify what their ideas are and to design valid tests of them. In practice, much time can be spent on mundane matters and it is necessary to put aside time to ensure that each group is able to proceed. Help is needed from the teacher to enable pupils to focus on their results and to relate these to their hypothesis. We found some groups of pupils were dissatisfied with the outcome of their investigations, and were prepared to be critical of their work. We encouraged them to suggest amendments. To enable teachers to plan ahead, it is necessary for pupils to design their investigation and to order equipment the lesson before the activity.

Some activities are designed to enable pupils to explore their understanding of the school science view and to give time for them to restructure their thinking. It is important to provide time for the discussion of the results of these activities to encourage pupils to become familiar with a range of views. The practical activities should be carefully chosen by the teacher in response to the needs of the class. The examples given in this scheme were selected to illustrate the main points outlined in the 'pupil notes'. The criteria we used in selecting these activities were that they provide reliable and consistent results in a short time. However, even though the activities selected may appear straightforward, our experience was that pupils do not find them easy to understand. Particular difficulty arose over the use of indicators.

A number of activities have been provided at the end of the scheme to enable pupils to apply their understanding of the school science view. Some of these activities involve practical work which may be teacher directed, but may equally be chosen by the pupils. When they undertake their own investigations, pupils are often well motivated and will wish to come to the laboratory during lunchtime and after school to check on the progress of their project. They also value recording their findings.

3.2 Written work

Our uses of writing in the scheme are as follows:

- as a means of helping pupils to identify and describe their own ideas. The ideas arising in the discussions are written down on posters as a record of group work. At other times pupils are asked to produce a written account of their own ideas
- as a vehicle for reflecting on and organising ideas. There is an emphasis on pupils expressing their thoughts in their own style of writing. The 'pupil notes' avoid the necessity of formal note making, and the pupils are expected to interact with these school science ideas to produce a written account of how their own ideas relate to this view
- as a means of informing a reader of the outcome of a piece of work. Pupils are encouraged to write in a clear and concise manner, but using their own language. If technical words are used then they should be to improve the clarity of the text, and not to impress the reader.

Here, it may be appropriate to comment briefly about marking. We found it inappropriate to allocate marks in the normal manner when assessing pupils' work that described their own ideas. However, we found that these pieces of work offered tremendous insights into pupils' thinking and were therefore valuable means of assessing the learning that was taking place in our lessons. Initial brief comments from teachers developed into written conversation with some pupils. In some cases we found pupils expected to be awarded a mark even though we were making our assessment criteria explicit to them.

3.3 Discussion

We have used discussion as a means of enabling pupils to identify their own ideas, and to become familiar with other people's ideas. We feel that this aim is achieved more readily in groups of no more than five individuals, and we have named this activity 'small group discussion'.

On other occasions discussions may involve the whole class as a single group; when the teacher wishes the class to focus on a single issue, such as familiarising the class with work produced by small groups or individuals.

Small group discussion

Discussion between pupils in small groups encourages the examination of an individual's ideas and also those of their peers. It may also act as a stimulus to promote further thinking.

We have found the following guidelines useful in promoting effective discussion:

- setting a size limit on each group. We would suggest that three or four is an optimum number
- ensuring that the task is clearly understood
- setting a time limit
- setting a goal, such as the production of a poster
- allocating an area of the room for each group, furniture to be moved into a suitable arrangement
- assigning particular tasks to individuals, such as spokesperson, note taker. The group may allocate their own tasks
- outlining some simple rules for effective discussion

- remaining in the background. Groups should be encouraged to think deeply around issues, but should not be offered judgements
- providing an environment where each pupil feels that their individual contribution will be welcomed and respected.

Whole class discussion

When discussing as a whole class, the teacher may wish that each pupil be made aware of the range of ideas held by the class, or may wish the pupils to focus on one particular issue. We have referred to the former activity as 'reporting back'.

Class discussion is difficult to run effectively as it can easily become a closed question and answer session. We have found it helpful for the teacher to adopt the role of neutral chairperson. This is easier if the teacher sits amongst the pupils and encourages them to ask each other questions. It is also helpful if the seating can be arranged so that maximum participation is possible. One strategy that we have found useful in involving all the class is to vote on important issues. Again, setting a time limit, say, of fifteen minutes helps to ensure pupils maintain their involvement.

At two points in the teaching scheme it is important for the whole class to be made aware of the activities of each of the small groups. The strategy that we used for this is 'reporting back'. Some pupils find speaking to the whole class rather a daunting task. We tried to ease this problem by:

- forewarning speakers and allowing rehearsal time
- arranging the class in a close amorphous group
- asking the speaker to stand, but not distancing them from their audience by making them stand at the front of the class
- preventing interruptions from other pupils until the report is completed
- setting a time limit for each report, for example, of two minutes

- summarising each point made on a blackboard or an overhead projector. This can be a checklist that is ticked or a listing of important phrases
- allowing reference to be made to posters or other material
- making sure that the final report is received with as much enthusiasm as the first
- encouraging, or asking leading questions.

3.4 Posters

Preparation

Pupil poster making is an important and integral part of the scheme. The purpose is to ensure that pupils can present their ideas in a way that is easily understood by the rest of the class, and also provides a permanent record of their work for future review.

The production of the poster provides a focus of attention for small group discussion and for reporting back. It also provides a tangible outcome from a discussion.

We have found the following guidelines useful:

- the purpose of the poster is to present ideas and therefore the standard of presentation should not become an important issue
- the materials for producing the poster should be distributed after pupils have spent sufficient time discussing their ideas
- pupils should put their names on their poster
- if one pupil in the group holds strong opinions that are not shared by others then they should be given the opportunity to make their own poster
- large sheets of paper (preferably A2) and large marker pens should be used whenever possible.

Display

As far as possible we tried to display the posters on the laboratory wall for the duration of the unit. This caused some discussion amongst ourselves as to whether we were prepared to display a wide range of ideas on a topic to other pupils, teachers and visitors. Our decision was that we should and this met with strong approval from both the pupils who produced the work and those from other classes. However, some teachers may feel more comfortable if posters are displayed under a heading which clearly indicates their status e.g. "Ideas of class 3W on how plants get their food."

These notes refer to teaching strategies particularly appropriate to this scheme. Further comments on teaching strategies can be found in the teacher booklet accompanying this scheme (6).

4 The teaching scheme: materials and plans

4.1 Introduction

For convenience the teaching materials have been divided into three sections, as shown in figure 2.1. These are:

- probing and testing pupils' ideas (lessons 1-3)
- presentation and exploration of school science ideas (lessons 4-5)
- application of school science ideas (lesson 6).

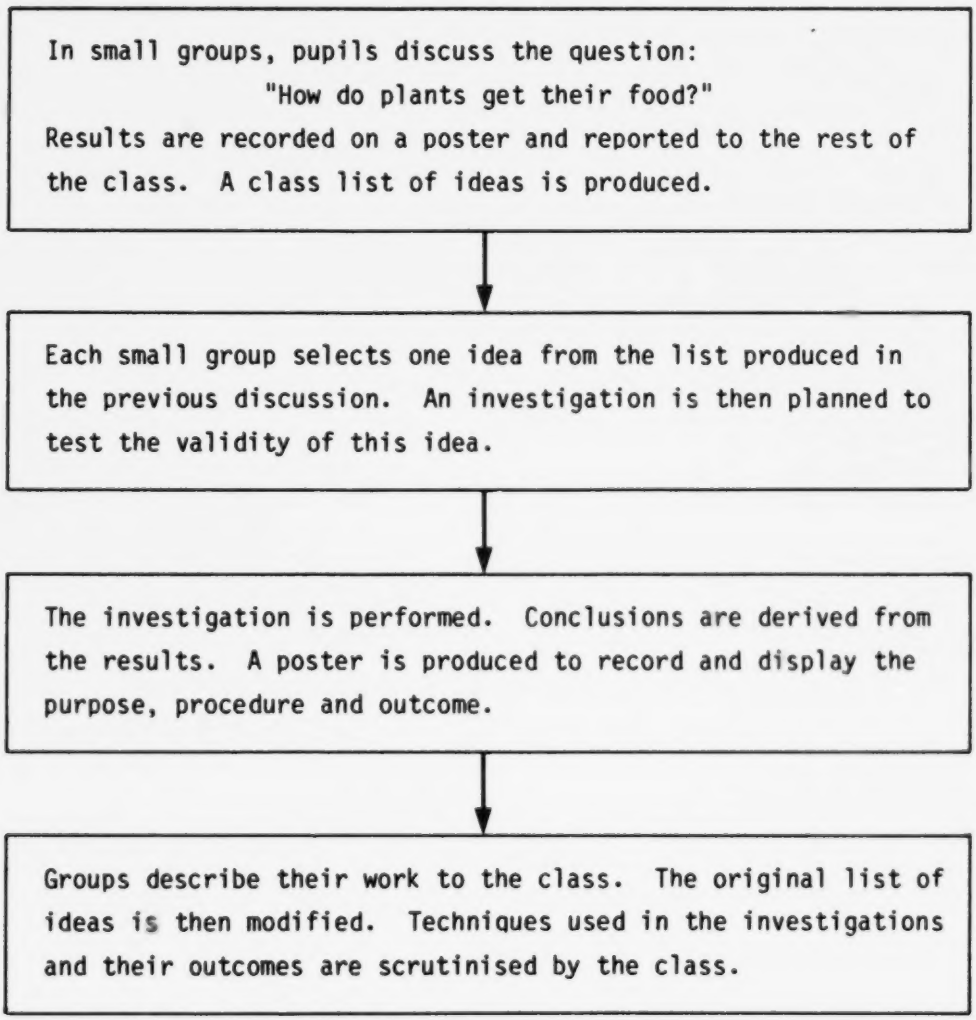
Each of the three sections includes:

- an outline and detailed lesson plans listing the focus of the lesson, pupil activities, teacher activities and necessary equipment.
- notes on how to manage each lesson and comments on how pupils respond to activities including some examples of pupils' work from lesson trials. It is hoped that these examples will help teachers to 'know what to expect' when they use the materials.
- worksheets and information sheets for each lesson, that may be copied for use within the school.

4.2 Probing and testing pupils' ideas: lessons 1, 2 and 3

The first three lessons help pupils to identify their own ideas on plant nutrition and to test these ideas experimentally. In the light of their experimental findings, pupils are then encouraged to re-examine their original ideas. By discussion, pupils become aware of the range of different explanations held by the class and also gain insight into some of the processes of scientific investigation.

TABLE 4.1 MATERIALS FOR PROBING AND TESTING PUPILS' IDEAS. OUTLINE OF LESSONS 1, 2 AND 3


In small groups, pupils discuss the question:
"How do plants get their food?"
Results are recorded on a poster and reported to the rest of the class. A class list of ideas is produced.
Each small group selects one idea from the list produced in the previous discussion. An investigation is then planned to test the validity of this idea.
The investigation is performed. Conclusions are derived from the results. A poster is produced to record and display the purpose, procedure and outcome.
Groups describe their work to the class. The original list of ideas is then modified. Techniques used in the investigations and their outcomes are scrutinised by the class.

Lesson 1

Focus	Lesson Activities		Equipment	Notes
	For the pupils:	**For the teacher:**		
Pupils' ideas on "how do plants get their food?"	Pupils form their own groups of 3-4 to discuss this question. Produce a poster to illustrate their answer.	Introduce the lesson with stimulus material. After explaining this task encourage responses, but do not comment on their 'correctness'.	Stimulus material e.g. large plant. Large sheet of paper and marker pen for each group.	
Sharing of ideas from class.	One person from each group reports to the class, using their poster for reference.	'Chair' the report back. Summarise the responses on OHP or blackboard. Encourage or ask for clarification when necessary.	Overhead projector and pen. Blu-tack.	
Clarifying and testing an idea.	Each group selects an idea related to how plants get their food.	Make a record of each group's selection. Provide design help when asked.	One worksheet per pupil.	
Homework:	Complete worksheet on experimental design, to allow preparation of apparatus.			

Lesson 1 Commentary

The intention in the first three lessons of the scheme is to help pupils become aware of their own ideas on plant nutrition, and those of their peers. These ideas may be clarified for the individual pupil through discussion, and tested out through experimentation. Towards the end of this process, pupils may then begin to examine their ideas critically.

The focus of this series of lessons is the question:

"How do plants get their food?"

We acknowledge that each individual will interpret this question in their own way, and that this interpretation will influence the ideas that are proposed by the class and how they are to be tested.

As the notes in an earlier section indicated many pupils think of food as something that is taken in from outside (for example, water and components of the soil).

If pupils are allowed to do their own investigations to explore how plants get their food at this stage many will focus on the substances plants take in. For example, a group of pupils planned to test whether water is a food for plants. They also considered that food is necessary for survival; therefore if a plant could not survive without water then water was indeed a food. This view obviously determined what they looked for in their experiment, i.e. the dependent variable was whether the plant lived or not! If pupils are testing out their ideas then the role of the teacher is to help them clarify their ideas and guide them in designing a carefully controlled experiment to test those ideas.

Some teachers preferred to focus on the meaning of 'food' as an energy-providing substance (such as starch or sugar) prior to giving pupils the task of investigating "how plants get their food." One teacher did this by referring the pupils back to the chemical test for starch that they had performed when studying human nutrition. This teacher then showed the class a technique for showing that starch was present in the leaf of a Pelargonium. A comparison between this more focussed approach and the earlier open approach is given in table 4.2.

TABLE 4.2 POSSIBLE TEACHER STRATEGIES WHEN ALLOWING PUPILS TO TEST THEIR IDEAS

"How do plants get their food?"

	'Open'	'Focussed'
Context:	allow pupils' interpretation	give school interpretation
Criteria for food (e.g.):	food is any external material taken in	food is a substance that provides energy
Criteria for test (e.g.):	does the plant grow? does the plant survive? does it look healthy?	is there any starch, glucose, protein present in the plant?
Examples of experiments carried out by pupils:	do plants survive without water, light, air, warmth?*	is there starch in soil? is there starch in the plant when it is deprived of light?
Teacher input:	after the investigation help class to consider the meanings of 'food', and whether each investigation was effective in testing the idea.	before investigation provide a framework for the pupils to work in, by reaching agreement on 'food' as an energy providing substance

* See examples of pupils' work for a fuller list.

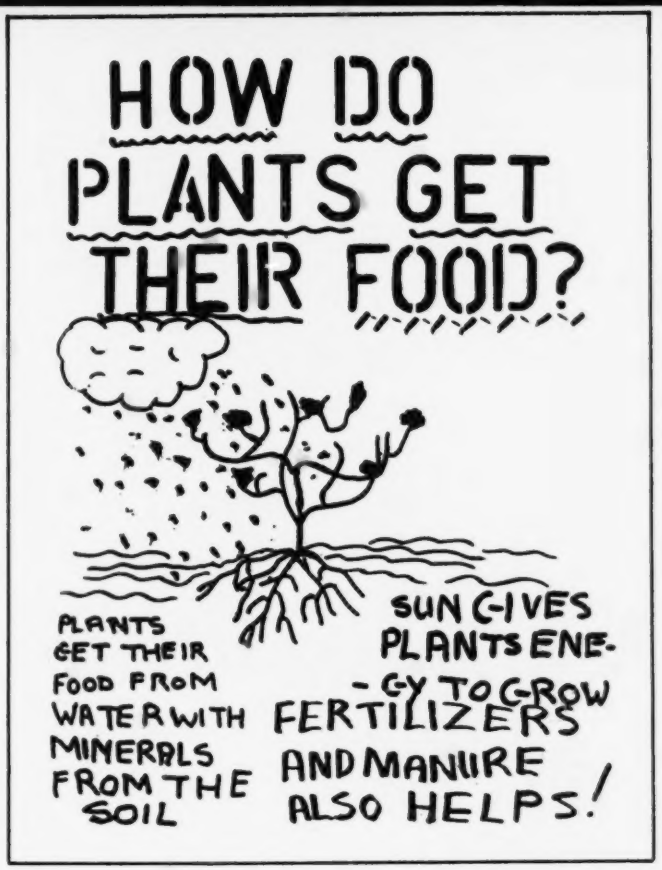
In this lesson an effort is made from the outset to provide an atmosphere in which pupils feel that their ideas and suggestions are valued. They are encouraged to speak openly and to be prepared to listen openly. This means not only preventing looks of surprise or disagreement appearing on our own faces, but also derision being voiced by other pupils.

After focussing pupils' attention on plants by using a variety of different strategies, pupils are asked "How do you think plants get their food?". They are then organised into groups and a few minutes are allowed for groups to settle. The question is restated and pupils are told to reach a consensus in their group. A time limit of about 10-15 minutes should be set during which time a poster (see figure 4.1) is to be produced to relate their ideas, and a spokesperson prepares for 'reporting back'.

Materials for posters are issued towards the end of this time interval to avoid distraction. There is little time for teachers to become involved with the discussions and we feel, in any case, that this may disrupt the free exchange of ideas. However, pupils should be disuaded from devoting too much effort to producing attractive posters, which may become time-consuming; it is the ideas that are most important.

The class is then reorganised for a 'reporting back' session to enable each pupil to become aware of each group's ideas. At first, pupils are hesitant to speak and need encouragement, such as "Yes, I find it scary to talk in front of people too", and "people want to hear your ideas".

Meanwhile, record each group's main ideas on an overhead transparency, blackboard or flipchart, ensuring that equal importance is attached to each response however similar to previous ones. On occasions spokespersons may be asked to amplify certain ideas if they are not clear. Do not allow criticism or judgement on the ideas at this stage, just clarification.


HOW DO PLANTS GET THEIR FOOD?
PLANTS GET THEIR FOOD FROM WATER WITH MINERALS FROM THE SOIL
SUN GIVES PLANTS ENE- GY TO GROW
FERTILIZERS AND MANURE ALSO HELPS!

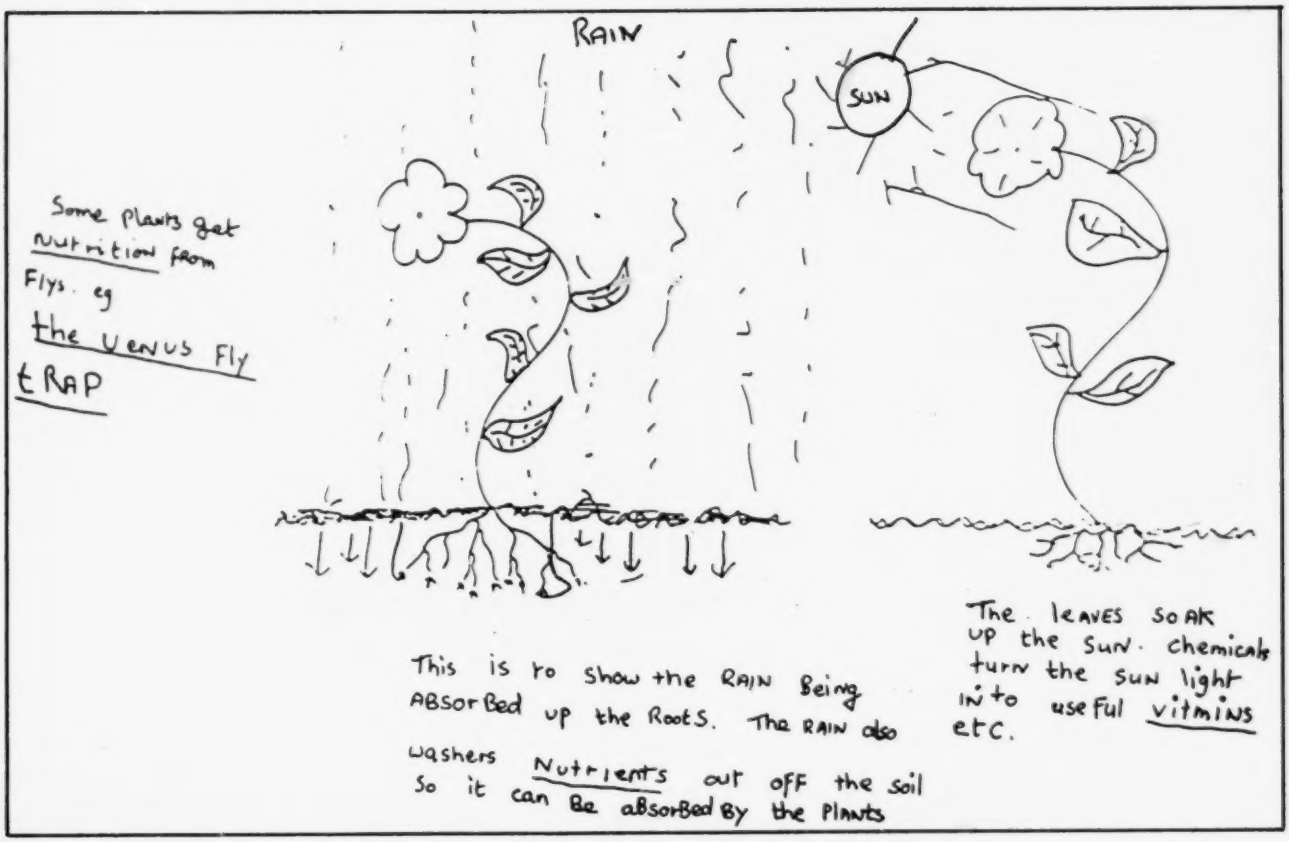

RAIN
SUN
Some Plants get nutrition from Flys. eg the Venus Fly tRAP
This is to show the RAIN being ABSorBed up the RootS. The RAIN also washers Nutrients out off the soil So it can Be absorBed By the PlANTS
The leAVES soAK up the SUN. chemicals turn the SUN light in to useFul vitmins etc.

Figure 4.1 Two examples of pupils' posters

Pupils' ideas often overlap and you can expect many to comment on the importance of sunlight, water, air and soil. (See figure 4.2 for a teacher's summary from lesson 1.)

Plants get their food from the soil.
Plants get their food from water/rain through the roots.
Sun is needed for plants to feed.
Soil is needed for plants to feed.
Air/carbon dioxide/oxygen is needed for plants to feed.
Minerals/manure provide food for plants.
Plants get food from the sun.
Water and soil react to make plant food.
Plants feed on insects.
Food enters through the petals.
Plants have tentacles on the roots for feeding.
Plants feed on dead leaves in the soil.

Figure 4.2 Teacher's summary of 'reporting back' session

Groups are then asked to design an experiment to test out an idea about "how plants get their food". For the remainder of the lesson, groups devise and plan their investigations. Worksheets are distributed to help pupils focus on important aspects of experimental design, namely:

- precisely what variable is to be tested
- how will the effect of a change in this variable be measured
- how will the effect of other variables be taken into account
- what materials will be required.

These sheets are completed for homework and returned to the teacher to allow some check on the approach and to enable apparatus to be prepared for lesson 2.

A copy of this worksheet is provided on the next page.

Our Experiment on How Plants Get Their Food.

Names of people in the group:

....

....

The idea we are testing is: .....

.....

.....

We are going to test it by: .....

.....

.....

.....

The change that we are going to measure is: .....

.....

.....

To make our experiment a fair test, we will: .....

.....

.....

The equipment we need is:

glassware	chemicals	instruments	plants	other items

Lesson 2

Focus	Lesson Activities		Equipment	Notes
	For the pupils:	**For the teacher:**		
Carrying out practical investigation.	Collect apparatus and set up investigation. Observe and record results.	Organise the distribution of apparatus. Assist groups when asked. Promote discussion, observation and interpretation of results.	As specified by groups.	
Describing the outcome.	Each group produces a poster to inform the class of their investigation.	Help each group to focus on their results. Stimulate discussion on possible improvements to procedure.	Paper and pens.	
If experiments need to be set up over a period of time it may be necessary to point out that each group should be responsible for their own apparatus. It may also be necessary to organise a rota for the watering of plants.				

Lesson 2 Commentary

The lesson begins with a reminder to the class that the purpose of their planned investigation is to test out their idea. Each group is directed to its tray of apparatus that is assembled in response to the preparation sheet completed for homework. We have found that pupils are keen to get started on their own experiments. The choice of which idea to test, and which method to adopt has been found to be a great motivator.

During this part of the lesson pupils sometimes need an encouraging response from the teacher, but we have found that they quickly gain in self-confidence.

The teacher may spend some time collecting together odd items of equipment which have been forgotten at the planning stage. We found it necessary to make a conscious effort to visit each group, and we tried to focus the pupils' thinking on their experimental design. There were some unusual strategies adopted, but provided they were safe, we intended that pupils should learn from their own experiences, rather than having weaknesses in design pointed out by the teacher. At a later 'reporting back' stage pupils have a chance to criticise each other's designs.

As the experiments are set up, provide paper and pens for the preparation of a poster. Each poster is to display the idea being tested, the method adopted, and the outcomes of the investigation. For the longer term investigations it is pointed out that space should be left in which to record the results and conclusion. Once more, point out that the quality of the content of the poster is more important than the quality of the presentation.

Arrangements are made at the end of the lesson to ensure that long term experiments are suitably accommodated and that they will be supervised throughout their duration.

Some teachers asked their pupils to keep a record of their experiment in their exercise books. This was set as a homework. We found that pupils were keen to come to the lab. to check their experiment periodically either in lunch hours or after school. Examples of experiments which pupils have undertaken are shown in table 4.3.

TABLE 4.3 EXAMPLES OF EXPERIMENTS SET UP BY PUPILS IN LESSON 2.

1. WATER

Do roots take up water? Does water go up the stem?
Small plant in methylene blue, sectioned, observed.

Are there holes in roots for water to get in?
Roots of Impatiens washed and examined using hand lens.

Is water needed for a plant to feed?
One plant watered, one not watered. Iodine test.

Do plants take in water by their roots?
Two plants - one with roots, one without roots.

Do plants feed on water?
Plant in blue dye solution, leave in light, cut stem and observe under microscope. Test for starch, glucose, protein and fat.

Is water a food?
Leaf in petri dish on dry cotton wool, another on moist cotton wool. Observe.

Do plants give out water?
Cover plant with plastic bag, leave, look for condensation.

2. LIGHT

Is light needed for a plant to feed?
Three plants - sunlight, dark, artificial light. Test leaves with iodine solution.

Do plants grow in sunlight?
One plant in dark, one in light. Measure growth.

Do plants need light?
Cress seeds on moist cotton wool. One in light, one in dark, observe growth.

3. SOIL

Is soil needed for a plant to get food?
One plant grown in vermiculite, another in soil, leaves tested for starch.

4. GASES

Do plants give out oxygen or carbon dioxide?
Elodea in inverted funnel with test tube on top, test with glowing splint and lime water.

Do plants grow better in oxygen or carbon dioxide?
One plant in pure oxygen, one in pure carbon dioxide, observe growth.

Do plants give out oxygen?
Plant in glass jar, test with glowing splint.

Do plants breathe in carbon dioxide?
Fill jar with carbon dioxide, test it with lighted splint, put plant in, leave, test with lighted splint again.

Lesson 3

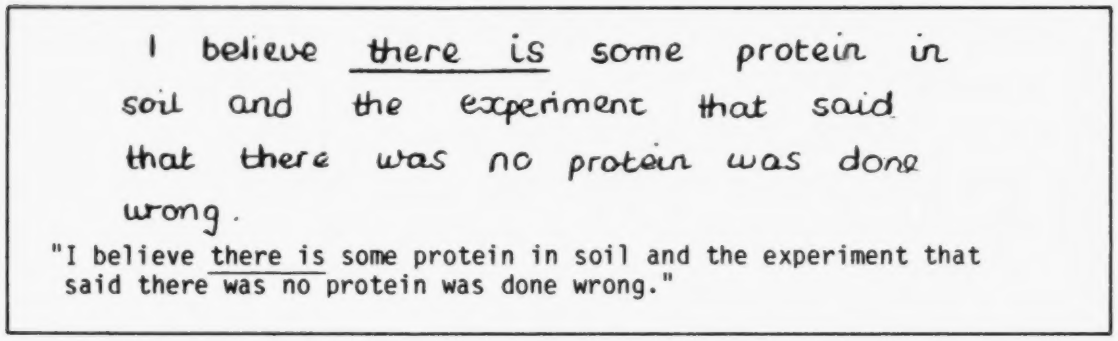
Focus	Lesson Activities		Equipment	Notes
	For the pupils:	**For the teacher:**		
The results of the investigations.	One person from each group reports to the class, using their poster, if necessary, as a prompt.	'Chair' the report back. Summarise the findings. Encourage questioning by pupils on findings and techniques.	Overhead projector and pen. Blu-tack.	
Review of original ideas.	Discussion by the whole class.	Refer to original posters and list of ideas. Promote discussion on ideas and the methods used to test them.	Original posters and list of ideas from lesson 1.	
Pupils review their own ideas.	Written response to homework question.	Set homework, emphasising the need for clarity and the importance of the pupil's own ideas.	Exercise books or sheets of paper.	
Homework:	Describe your ideas on how you think plants get their food.			

Lesson 3 Commentary

Time is allowed at the start of lesson 3 for the completion of any investigations that are carried over from lesson 2.

Materials and instructions are then provided for the preparation of a poster if this was not done in lesson 2. After we had ensured that each group had settled into their work, we found it useful to help pupils to focus on their results, and to help them relate the results to the problem being investigated.

There was a tendency for some groups to gloss over anomalous results in order to seek reinforcement of their original hypothesis. Sometimes pupils may report that the experiment is "done wrong" because unexpected results are obtained.



"I believe there is some protein in soil and the experiment that said there was no protein was done wrong."

After allowing preparation by each spokesperson, the groups reconvene as a class to hear about each experiment. Once more, the teacher should record a summary of each report on an overhead projector. Questions and comments are encouraged if these seek clarification of a point, or if they are supportive in suggesting modifications.

The posters (see figure 4.3) are then displayed on a wall in view of the class. The ensuing class discussion focusses on three issues:

- what are the different meanings of 'food'?
- do the experiments reveal anything about how plants get their food?
- can the experiments be improved in any way?

We found that this lesson was rather rushed. In classes where pupils' investigations carry over from lesson 2 there may be insufficient time for an adequate discussion of these issues. Teachers may wish to extend the discussion by carrying it over into the next lesson.

DO PLANTS TAKE IN SUGAR?
Roots
Leaves.
We tested for Starch and Glucose
METHOD.
WE TOOK A PLANT AND PLACED IT IN 2% OF GLUCOSE. THEN WE LEFT IT FOR A WEEK TO SEE IF IT TOOK ANY OF THE SUGAR IN
RESULT
We tested a leave and found no sugar or starch we then tested a root and found no starch but there was some sugar.
2% Glucose

Figure 4.3 Example of a pupil poster recounting an experiment

This sequence of three lessons gives pupils the opportunity to design, carry out and evaluate their own experiments. The sorts of things they can appreciate through this include:

- the need to clarify ideas prior to designing experiments
- the need to undertake controlled experiments
- the possibility of alternative interpretations of data.

In addition, we would hope that pupils may begin to question some of their original ideas. To give them the opportunity to reflect on their own ideas and how these have changed, they are asked to describe how they think plants get their food, as a homework activity. Pupils are encouraged to give a full and detailed response, and emphasis should be put on the individual nature of this exercise.

Some teachers may be wary of asking pupils to write their own ideas in their exercise book which may later be used for revision. If a suitable title (for example, "My own ideas about...") does not solve the problem, the work may be done on sheets of paper. (Some suggestions for marking pupils' work are given in (6).)

How I think a plant gets its foods

I presume plants get their food through tentecles (which are very small), which are connected to the roots of the plant. The food which is likely to be minute pieces of minerals goes up the roots, up the stem and into the small branches which are connected to the leaves In the leaves the food (minerals) passes through kinds of veins which then feeds the leaves and makes them green. This goes on throughout the plant.

I think that when we water the plant and when the water gets in the soil, the soil and water mix which make the minerals.

diagram.

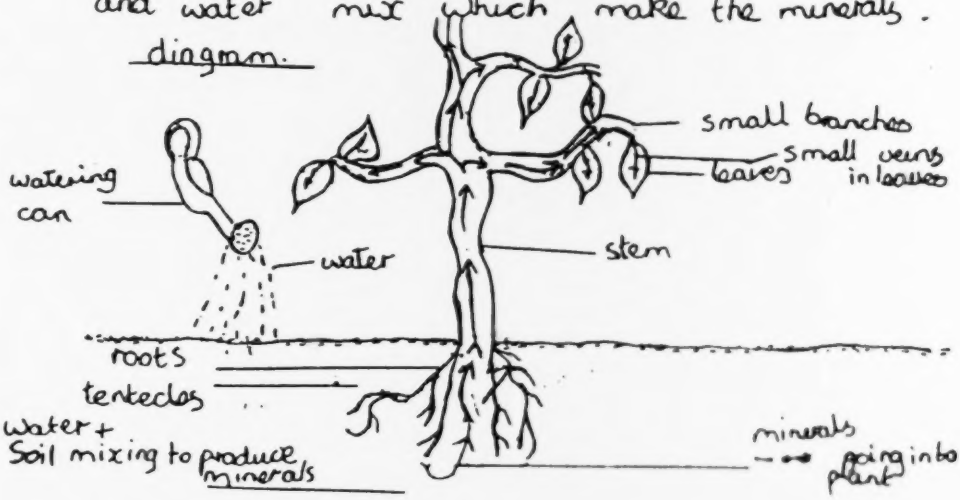


Figure 4.4 An example of a 13 year old pupil's homework

4.3 Presentation and exploration of school science ideas: lessons 4 and 5

The class should, by this stage, have explored their own ideas about how plants get their food. A number of issues may have arisen which may be puzzling, contradictory or interesting for pupils.

The strategy adopted in the scheme at this point is to present pupils with an overview of a scientific perspective on plant nutrition. This is presented as a set of ideas that is currently adopted by scientists, but it is pointed out that these ideas are a theory and may change. They have been found, over a number of years, to be useful in explaining certain things, but we cannot be sure that they are correct.

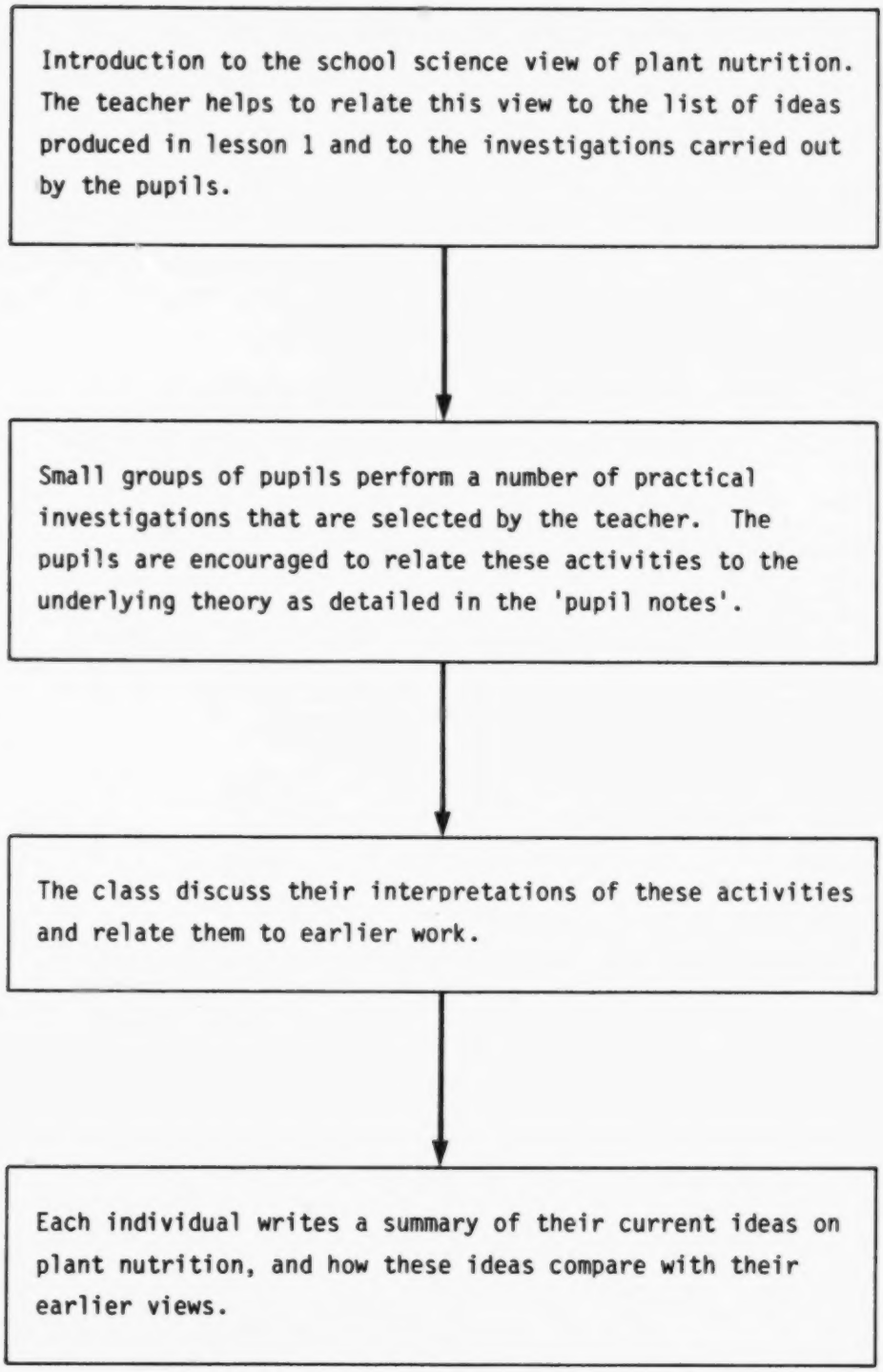
The scientific view has been produced on handwritten sheets to avoid the necessity for copious note-taking. Pupils are encouraged by the teacher to add to the notes and to relate them to their original ideas and experiments.

Several activities are provided by the teacher to enable pupils to explore their understanding and to provide a focus for discussion. The particular activities performed by the pupils may be selected from the list provided.

A discussion of each investigation should also enable pupils to clarify their ideas.

Each pupil is then asked to write a personal account of the change in their ideas over the course of these lessons.

TABLE 4.4 MATERIALS FOR FAMILIARISING PUPILS WITH THE SCHOOL SCIENCE VIEW. OUTLINE OF LESSONS 4 AND 5.


Introduction to the school science view of plant nutrition. The teacher helps to relate this view to the list of ideas produced in lesson 1 and to the investigations carried out by the pupils.
Small groups of pupils perform a number of practical investigations that are selected by the teacher. The pupils are encouraged to relate these activities to the underlying theory as detailed in the 'pupil notes'.
The class discuss their interpretations of these activities and relate them to earlier work.
Each individual writes a summary of their current ideas on plant nutrition, and how these ideas compare with their earlier views.

Lesson 4

Focus	Lesson Activities		Equipment	Notes
	For the pupils:	**For the teacher:**		
The school science view of plant nutrition.	Read notes and ask questions.	To present the current scientific view and to relate this to the pupils' own ideas.	One copy of the 'pupil notes' for each pupil.	
Practical evidence for the scientific view.	In small groups, the pupils conduct some practical activities selected by the teacher.	Help each group relate their results to their own ideas and to the scientific view.	Materials from the list of investigations.	
Relating the activities to theory.	Class discussion.	The teacher chairs the discussion, reinforcing important points and explaining if necessary.		

Lesson 5

Focus	Lesson Activities		Equipment	Notes
	For the pupils:	**For the teacher:**		
The school science view of plant nutrition.	Read notes and ask questions.	To present the current scientific view and to relate this to the pupils' own ideas.	One copy of the 'pupil notes' for each pupil.	
Practical evidence for the scientific view.	In small groups, the pupils conduct some practical activities selected by the teacher.	Help each group relate their results to their own ideas and to the scientific view.	Materials from the list of investigations.	
Relating the activities to theory.	Class discussion.	The teacher chairs the discussion, reinforcing important points and explaining if necessary.		
Comparing ideas.	Written response to homework question.	Explain the importance of comparison in this homework.	Exercise books or sheets of paper.	
Homework:	Compare your ideas on how plants get their food with those described in the notes.			

Lessons 4 and 5 Commentary

By reading the responses to the homework set the previous week, we found that we had a fairly clear picture of the prevalent ideas on plant nutrition held by our pupils.

In these lessons, the school science view is presented to the pupils who are encouraged to relate this view to their own ideas, and to explore the school science view by conducting some teacher-prepared investigations.

The view that we put forward to our classes is that presented in the following pages of 'pupil notes', headed "How plants get their food". The practical work, which we planned to be reliable, and reasonably quick and easy to understand, is outlined at the end of this lesson commentary, and relevant worksheets are provided. We have also included some notes on the ways our pupils interpreted these activities when they carried them out.

We feel that teachers should make their own selection from the notes and practicals according to the needs of their pupils and their own circumstances. For some groups of pupils it may be inappropriate to use all five sheets of the 'pupil notes'. Other teachers may wish to proceed further by adding more detail. We found that three practical activities in one double period was the most that could be covered effectively. It is not intended that all the practicals in the list should be attempted.

It is important that the pupils should interact with the notes in order to begin assessing the ideas presented alongside their own. We tried several methods for this:

- reading the notes aloud as a class
- reading in groups
- silent, individual reading
- presenting the notes on an overhead
- comparison of ideas with those on posters
- questioning from the teacher.

The notes are printed as five sheets, for convenience, but it is necessary for individual teachers to decide on how many of these sheets should be presented to the class in one lesson. We based our decisions on the outcomes of lesson 3, to avoid introducing new areas before the initial ideas of light, water and carbon dioxide were clarified. The time taken for this part of the lesson should not be underestimated. We mainly chose to acquaint pupils with the first three pages of the notes, and the first four practicals in the list in lesson 4, dealing with the remainder in lesson 5.

The similarities and differences between the 'class ideas' and the 'science ideas' presented in the notes are drawn out by discussion. Where possible, the evidence provided by the pupils' own investigations in earlier lessons are also related to the notes, and pupils are encouraged to add annotations to their sheets where appropriate.

A series of practical activities is then provided, to help pupils explore their understanding of the theoretical material, and to provide evidence for some of the statements made. It is important that pupils are clearly focussed on the reason for doing these activities, i.e. to use the ideas they have been presented with in order to make sense of what they observe.

Pupils found some of the activities difficult to understand and needed some help from teachers. In particular the use of indicators caused confusion, especially when trying to interpret a colour change in terms of the underlying cause. Often a partial colour change was not recognised as a positive result. As these activities were performed the pupils were asked once more to add relevant information to their copies of 'pupil notes'.

Towards the end of each lesson, we found it necessary to discuss the pupils' understandings of each of the activities.

To help pupils recognise any changes in their ideas over recent lessons they are set a written homework question which asks them to compare their ideas as described when they had completed their own experiments (lesson 3), with their ideas at the end of lesson 5. We found that pupils frequently wrote at length when set this task, and their answers revealed considerable depth of thinking. It became apparent when marking this work that individual pupils had usually made considerable changes in the way they viewed this

topic, but that there was a range of levels of understanding. Most pupils considered this to be an interesting and important activity.

An example of one pupil's answer to this homework is shown in figure 4.5.

The differences of what I learned last week on plants on what I learned this week on how a plant gets its food

In the last homework I did not write how a plant gets its energy.
The plant gets its energy from the sun which shines its beams on to the plant The plant then has green coloured cells called chlorophyll which absorbs the the energy.
The energy which is absorbed by chlorophyll is used to build up sugar.
(which is carbonhydrate)
Carbonhydrate contains Carbon, hydrogen and oxygen. The carbon and oxygen comes from carbondioxide in the air.
The hydrogen is ~~dest~~ obtained when the light energy splits up water
Any sugar which remains is taken to other parts of the plant which can not make their own (eg roots, buds, stems and seeds)
Also the sugar may be built up into starch to be starch.

Figure 4.5 A pupil's review of the change in their ideas

How plants get their food

A

All living things – both animals and plants – need substances from outside their bodies to help them live and do things like growing and reproducing. They also need energy to do all this work, and the energy comes from outside their bodies too

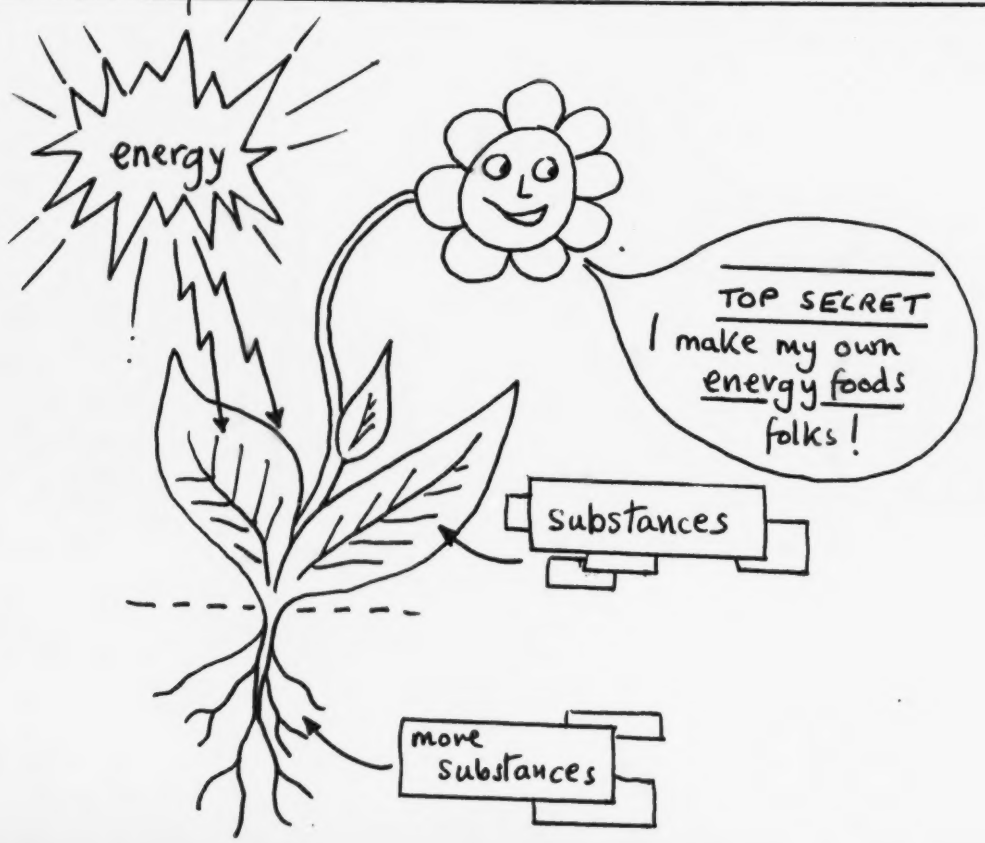
B

What about energy foods? – like sugar, starch and fats?

We eat our food, but obviously this is not possible for plants. They usually grow in soil, from where they get water – but soil does not provide energy foods!

where do they get energy foods?

THEY MAKE THEIR OWN!



C

So, how do they take in some energy to make their energy foods?

Well, they need two things to do this :-

① an energy supply

② something to absorb the energy

their energy supply is light usually from the Sun

they absorb the light energy using chlorophyll

the green colour in their cells which all plants feeding this way must have

D

But, how is the energy used to make energy foods?

The light energy absorbed by chlorophyll is used to build up sugar

This is made from carbon dioxide and water

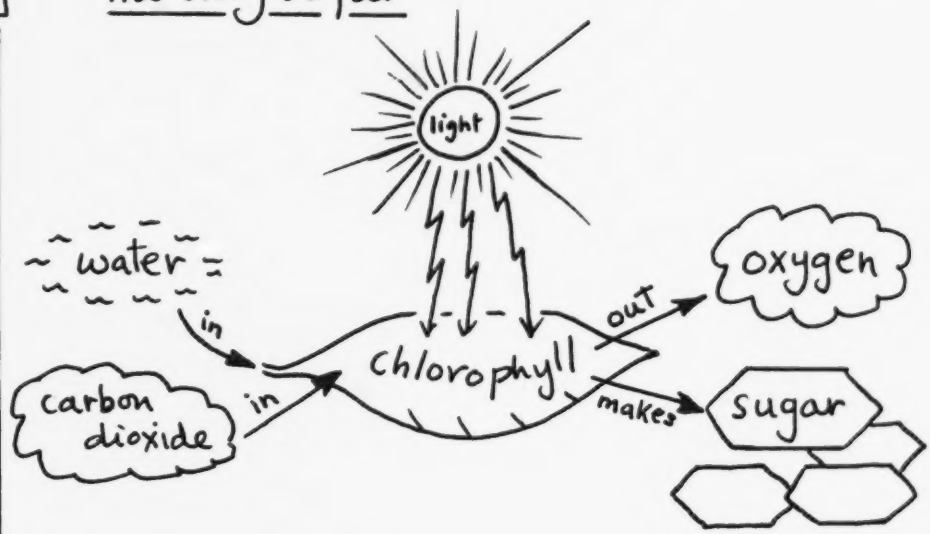
Carbon dioxide goes into the leaf through tiny holes

Water goes into the plant through the roots

Oxygen left over in the process — is given off.

E

The story so far



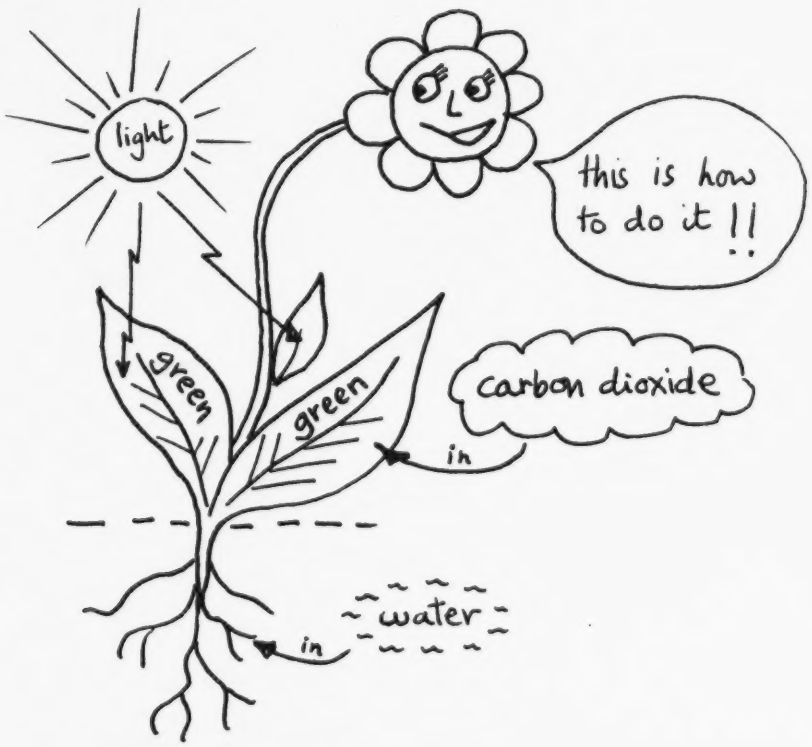
This is called

PHOTOSYNTHESIS

We give it this name

because 'photo' means LIGHT and 'synthesis' means BUILDING UP

Meanwhile, back in the field ↴

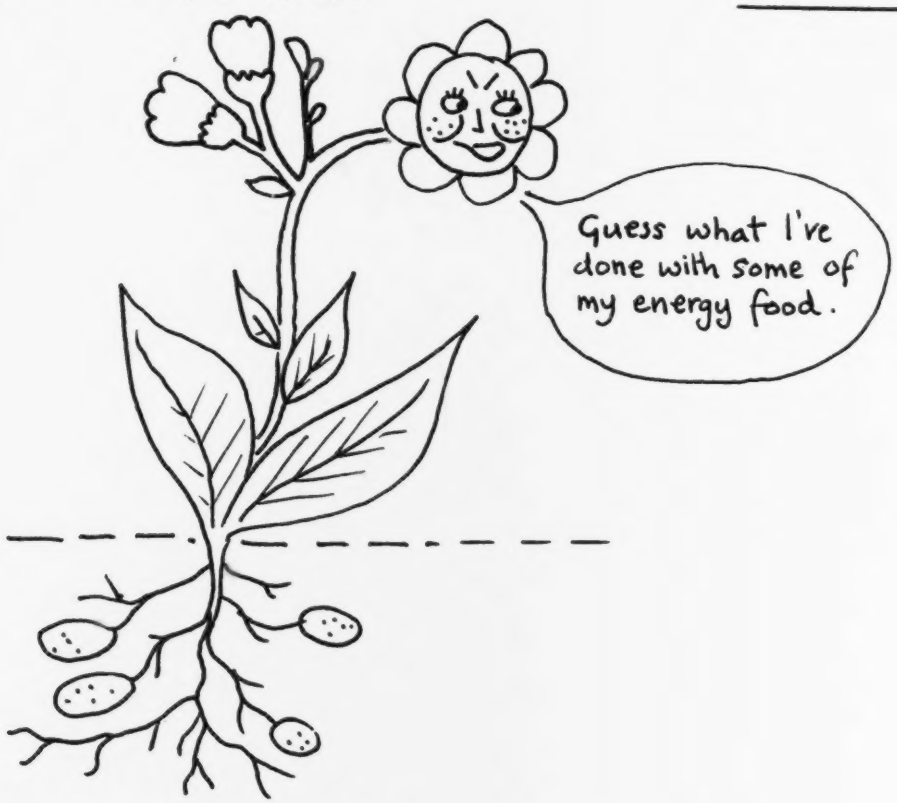


F

So what happens to the sugar which is not used straight away?

① It is taken to other parts of the plant which cannot make their own,
such as roots, buds, stems and seeds

② the sugar may be built up into [starch] to be stored.



G

So, how does the plant make other foods?

Photosynthesis builds up sugar first, for energy food, but to grow well, and keep healthy plants need to make other foods too like proteins for growth

This requires [mineral salts] which are taken in through the roots with the water supply.

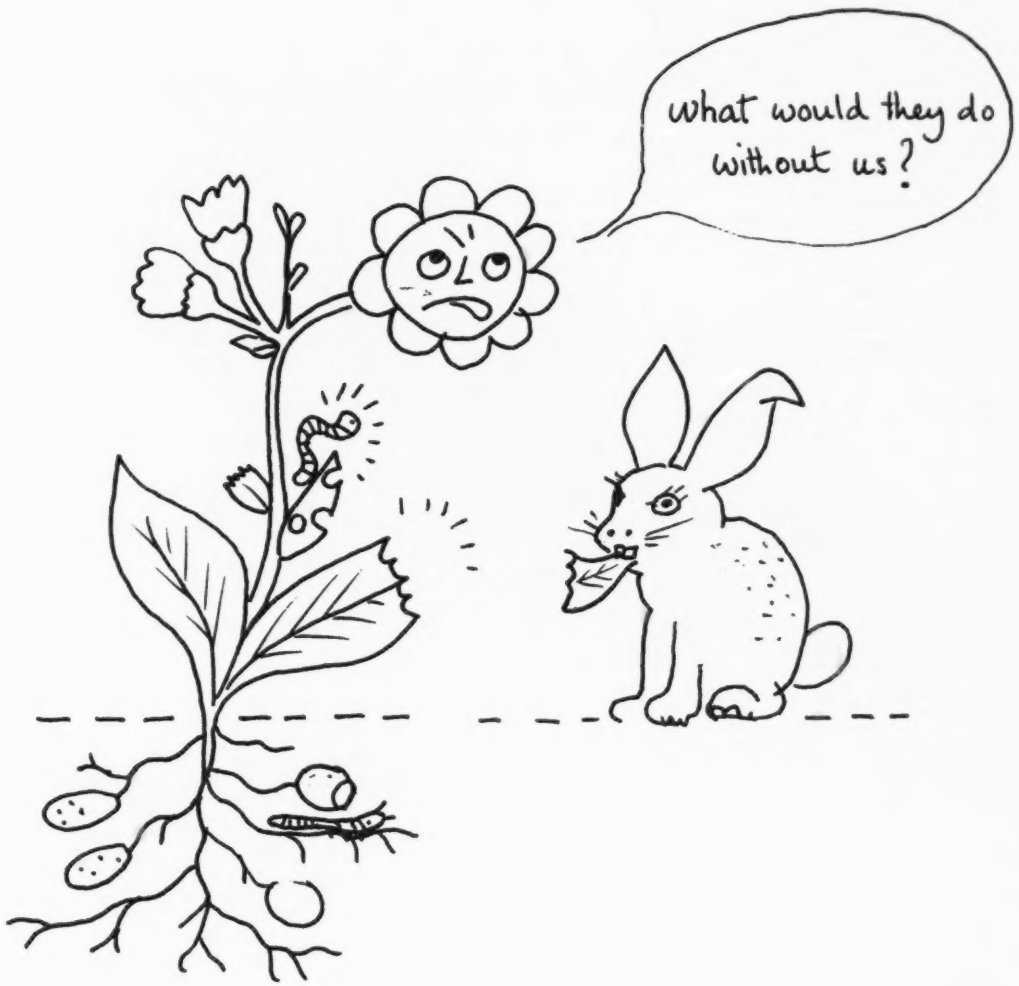
H

Right then, why are plants important?

① they make energy foods for themselves and for the animals which eat them.

② they give out oxygen, needed by all living things

③ they use the carbon dioxide breathed out by all living things.



Suggested practical activities for lessons 4 and 5

The following is a list of possible practical activities which can be used to reinforce the points made in the 'pupil notes' "How plants get their food". Worksheets accompanying these activities can be found on pages 57-64.

1. Chlorophyll absorbs light energy

When a solution of chlorophyll is placed in light, blue and red wavelengths are removed from the spectrum and absorbed by the chlorophyll for transformation into chemical energy.

A solution of chlorophyll may be prepared by crushing young leaves in ethanol and then filtering the resulting solution. Spinach (fresh or frozen) or nettle (fresh or powdered) are particularly suitable for this preparation.

The easiest method of providing a spectrum is by using a hand held spectroscope, but projected spectra using a prism or photographic slide are also suitable.

Some pupils believe that the role of chlorophyll is to prevent the entry of red and blue light into the leaf. We have also found that pupils do not necessarily appreciate that coloured light is the result of a subtraction of component wavelengths from white light. They see it as an addition to white light. It can be shown that colours are removed from the spectrum, not added, by removing the chlorophyll solution from the light path and then replacing it.

Discussion helps pupils to distinguish words like 'reflect' and 'absorb' which they tended to use synonymously.

2. Light energy

Light is a form of energy that is transformed into chemical energy during photosynthesis. The purpose of this activity is to help pupils recognise light as a form of energy, and that light energy may be transformed into other forms.

Pupils are asked to describe what happens when a piece of board is placed between a Crookes' radiometer and a light source.

In their discussions we found that pupils do not necessarily interpret their observations as might be expected. We noted, for example, that some pupils suggested that "there is white light and there is black light. The white light is the most powerful". In some cases pupils' interpretations were partial. For example, some suggested that "the vanes turn because they absorb light and heat energy" or "the turning vanes have light energy". In these cases pupils may need help to extend their interpretations through careful discussion with the teacher.

Overall, this activity helps most pupils to see that light is a form of energy even though they may find it harder to appreciate that light energy is being transformed into kinetic energy. Discussion of other light energy transformations, such as chemical changes to photographic emulsions may further pupils' understanding in some cases, although it should be realised that pupils may need help in appreciating the relevance of this activity to plant nutrition.

3. Chlorophyll is needed for making starch

A variegated Pelargonium should be kept well illuminated for several days. As pupils find decolourising leaves to be a complex procedure (2) we suggest that suitable leaves are prepared for their use in this activity. Leaves should be dipped in boiling water until soft, and then boiled in ethanol (using a waterbath) until decolourised. Finally the leaves need rinsing before use.

After recording the appearance of fresh and decolourised variegated leaves the pupils add iodine solution to detect the presence of starch. We have found that most pupils successfully complete the investigation and record the expected results but some had difficulty in interpreting the colour changes. For example, some believed that iodine replaced the colour that the ethanol had removed.

A reasoned explanation of how the leaf was treated is necessary to help pupils understand the appearance of the decolourised leaf.

Links may need to be made between this activity and using iodine solution to show the presence of starch in the human diet. We found that pupils were uncertain of how to interpret negative or partial results. Some believe that because the leaf margins are turned orange by iodine solution then these parts contain a different substance, such as glucose.

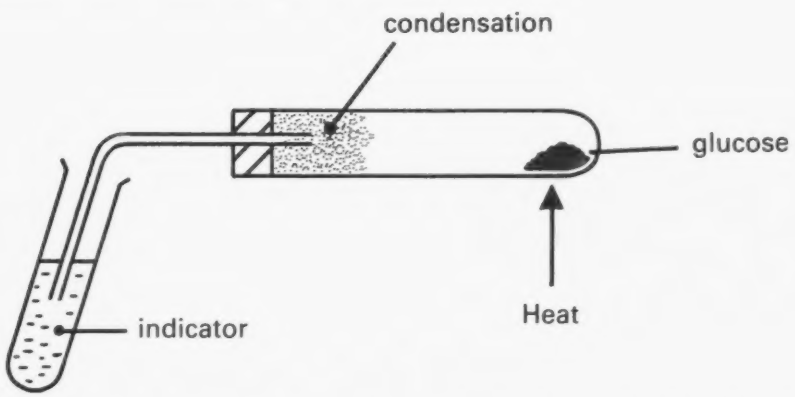
4. Sugar is present in leaves which have been in the light

We chose to show that light is necessary for carbohydrate production using the presence of glucose rather than starch because of the difficulty pupils experience when testing leaves with iodine solution (2).

Iris and Amaryllis leaves contain enough sugar when grown in the light to show a clear change when pulped and tested with diabetic test strips (e.g. Clinistix). Benedict's solution may be used as an alternative test, but this involves a more complex procedure. The results obtained may be compared to similar tests performed on leaves deprived of light for several days.

It would be helpful to explain the purpose of the test strips and some pupils may experience difficulty in interpreting the colour change from the information provided with the strips. We have found that through discussion of this activity most pupils understand the relationship between sugar, leaves and light.

5. Glucose contains water and carbon dioxide



When glucose is heated strongly, carbon dioxide is evolved and water vapour condenses around the rim of the test tube. During photosynthesis carbon dioxide and water are combined to form glucose. We found that pupils

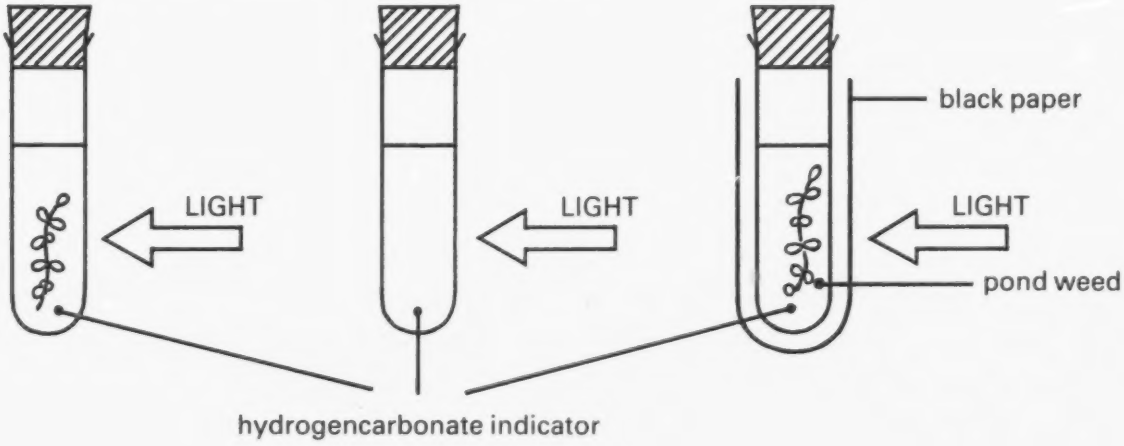
readily understand the link between these two processes when performing this practical activity and describe one reaction as being the reverse of the other.

Carbon dioxide is detected by limewater changing from colourless to milky, or by hydrogencarbonate indicator changing from deep red to orange. Pupils may need help in recognising these changes, and inferring that the changes are due to the presence of carbon dioxide. A further point to raise in discussion is how could it be confirmed that the condensation in the heated test tube is water.

If this activity is to be discussed in terms of reversibility of energy changes a point of confusion may arise. When glucose is formed in photosynthesis, energy is transformed into chemical energy. During the combustion of glucose chemical energy is transformed into heat. However, the glucose initially requires heating to supply activiation energy, before combustion can occur. Pupils may not understand that foods such as glucose release energy if they do not appreciate the purpose of providing heat to initiate this reaction.

Goggles should be provided for use by pupils when performing this activity.

6. Plants absorb carbon dioxide in the light



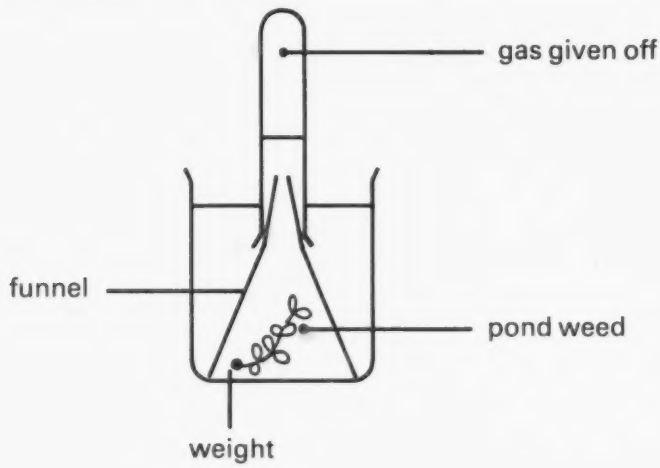
If pond weed, such as Elodea, is immersed in hydrogencarbonate indicator and illuminated for twelve hours, the indicator changes from red to dark red, showing an increase in pH. This is due to the absorption of carbon dioxide by the plant.

When deprived of light for a similar period the evolution of carbon dioxide by the plant causes the indicator to change from red to orange.

Pupils can get quite confused in their interpretations of their observations from this activity. Some care may be needed to help them think through the causes of the changes in colour of the indicator. The reasons for using water weed should be explained as pupils do not always link gaseous exchange in terrestrial plants with that in an aqueous medium.

Note: Hydrogencarbonate indicator needs to be equilibrated with air prior to use.

7. Plants give out oxygen in the light

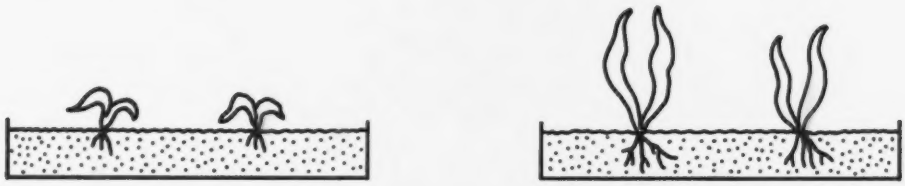


For convenience, the evolution of gases (mostly oxygen) by an aquatic plant has been used for this activity. The reasons for using aquatic plants may need to be pointed out to pupils, and it should be emphasised that a similar process occurs in terrestrial plants, as explained in activity 6.

Elodea water weed may be purchased fresh from aquarium suppliers. The stem should be cut cleanly with a sharp blade and the tip of the shoot weighted to allow the cut end to float uppermost. When brightly illuminated, bubbles of gas should evolve from the cut stem. Over a period of twelve hours sufficient gas will be collected in a narrow bore test tube to relight a glowing splint.

A comparison with a similar apparatus and plant left in the dark shows that this process only occurs in the light.

8. Healthy plant growth requires minerals



1
Given pure water only

2
Given water and mineral salts

Maize seeds sown in a mineral-free medium begin to germinate in about ten days. Suitable media for planting are washed sand or vermiculite (a granular mica compound) available from supermarkets and garden centres.

By watering one sample with deionised water, and the other with a solution of liquid fertilizer, such as 'Baby Bio', signs of mineral deficiency are recognisable within three weeks of sowing.

Pupils describe healthy growth as: bigger, tall, thicker, strong, brighter green. The seedlings in the mineral free culture are described as: withered, fallen, pale, weepy, wilting and broken. The only source of confusion we recorded was due to a failure to read the labels carefully on each container of seedlings.

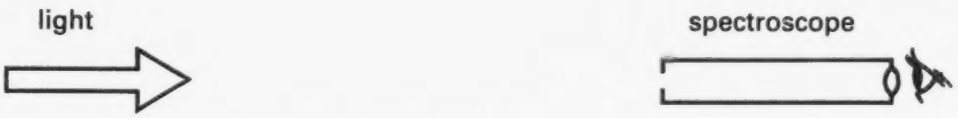
Further information about pupils' reactions to these activities may be found in (4). Pupils feel that it is important that they perform the investigations themselves. Demonstrating the results alone is viewed in a similar manner to 'being told' or 'looking it up in the textbook'.

Each of these activities needs to be reviewed carefully to help pupils make their interpretations. In the class discussion some input by the teacher is useful to help pupils see how the different aspects link together into a global view of plant nutrition.

WORKSHEET 1

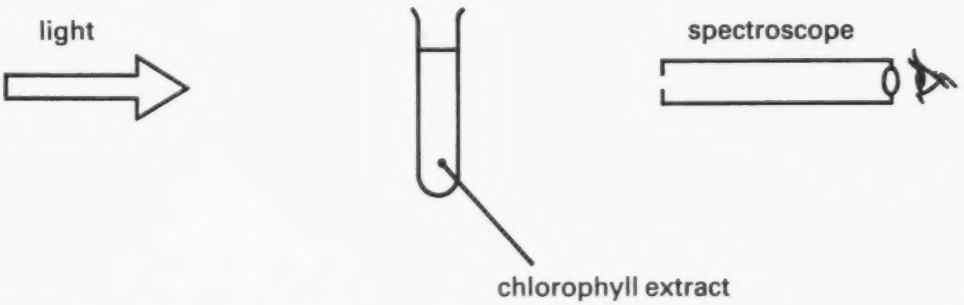
CHLOROPHYLL ABSORBS LIGHT ENERGY

* Point the spectroscope towards the light.
* Look through it.



1. Write down what you see.

* Now put the test tube of chlorophyll between the light and the spectroscope.
* Look through it again.



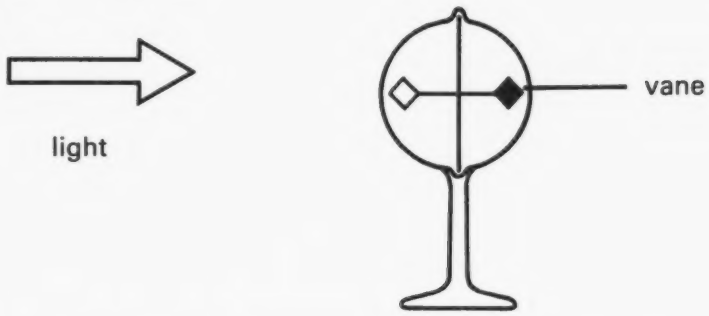
2. What changes did you notice?

3. What has happened to the missing light?

WORKSHEET 2

LIGHT ENERGY

* Stand the apparatus in the light.



1. What form of energy is making the vanes turn?

2. What kind of energy is in the turning vanes?

3. Where has the energy in the turning vanes come from?

* Put the board between the light and the apparatus.

4. Write down your reasons for what happened.

This is an energy conversion. In plants light energy is changed into chemical energy.

WORKSHEET 3

CHLOROPHYLL IS NEEDED FOR MAKING STARCH

* Examine the fresh leaf.
* Draw on the outline below which parts are green.

* Take a leaf which has had the chlorophyll (green colour) removed.
* Add some iodine solution to this leaf. Iodine solution is usually dark orange colour. It changes starch to dark blue.
* Draw on the outline below which parts contain starch.

Why is chlorophyll needed to make starch?

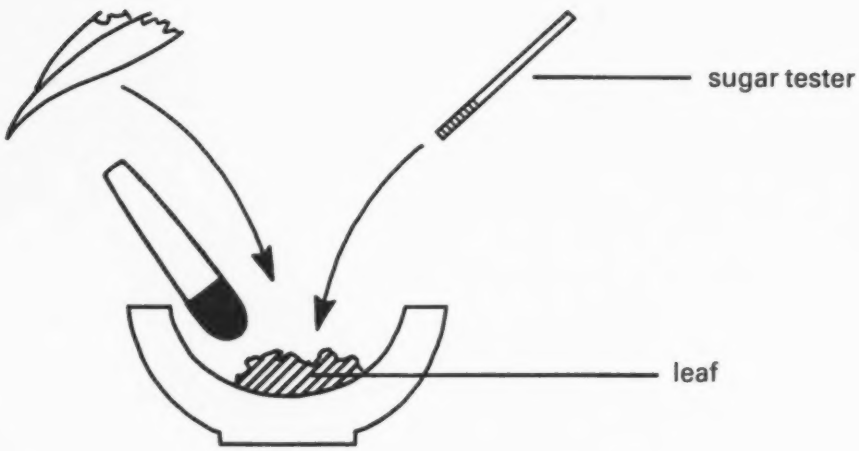
WORKSHEET 4

SUGAR IS PRESENT IN LEAVES WHICH HAVE BEEN IN THE LIGHT

* These leaves are from a plant which has been kept in the light.

* Crush a piece of the leaf.

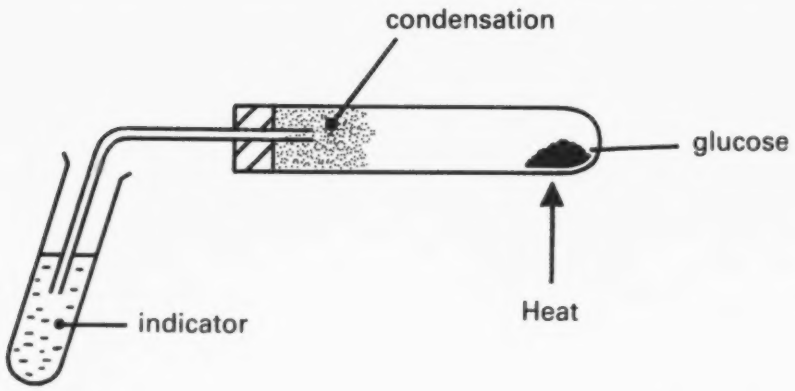
* Test the crushed material with the 'sugar tester'. If sugar is present the tester turns blue.



Describe what happened.

WORKSHEET 5

GLUCOSE CONTAINS WATER AND CARBON DIOXIDE



* The glucose has been heated strongly.

* Look carefully at the demonstration.

1. What can you see in the tube apart from the burnt glucose?

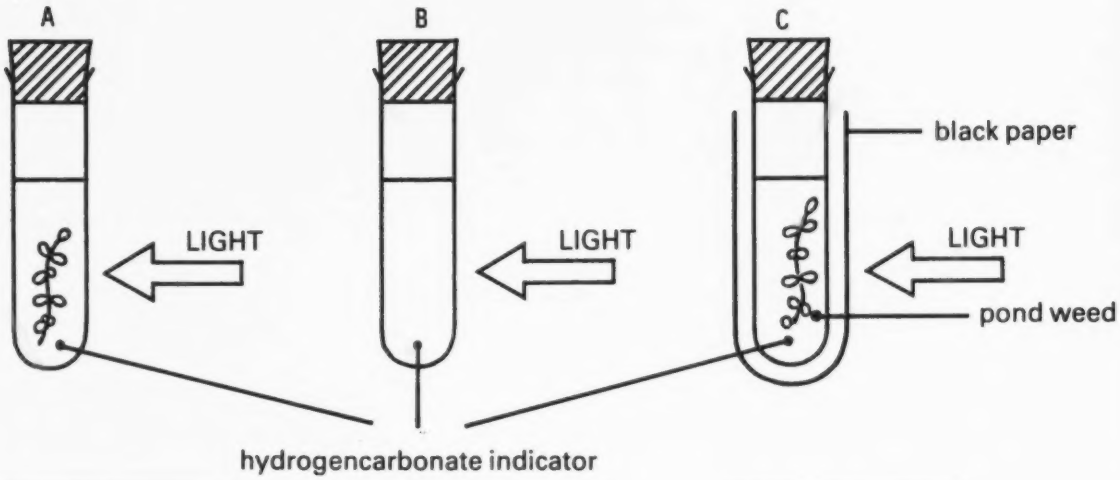
2. What colour is the hydrogencarbonate indicator?

3. What does this colour tell you about the gas that has been given off by the glucose?

4. What substances does glucose contain?

WORKSHEET 6

PLANTS ABSORB CARBON DIOXIDE IN THE LIGHT



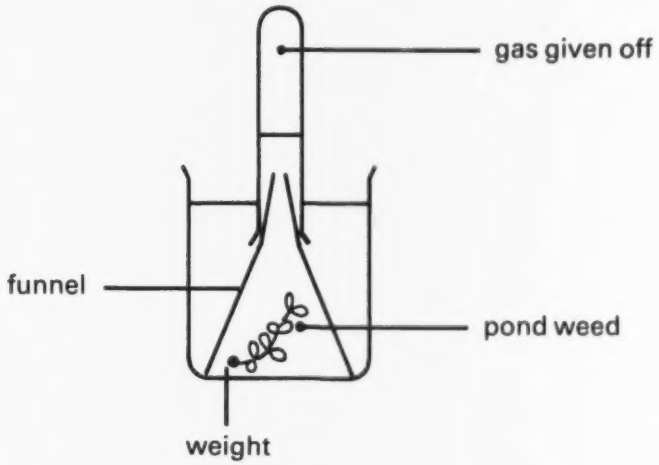
Results:

Hydrogencarbonate indicator is used as a test for carbon dioxide. It is red in laboratory air. In high concentrations of carbon dioxide it is yellow. Without carbon dioxide it is purple/dark red.

1. Write the colour of the indicator in the box under each tube.
2. Explain the colour of the indicator in Tube A.
3. Explain the colour of the indicator in Tube C.
4. Is there more or less carbon dioxide in Tube A than in Tube B?
5. Where has the carbon dioxide from Tube A gone?

WORKSHEET 7

PLANTS GIVE OUT OXYGEN IN THE LIGHT



* Carefully remove the test tube; put your thumb over the end of the tube.

* Test the gas with a glowing splint.

1. Describe what you saw.

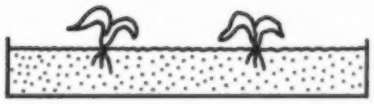
2. What gas was present in the tube?

WORKSHEET 8

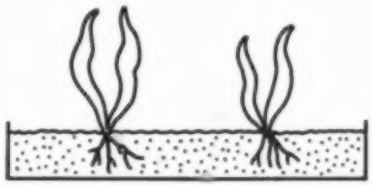
HEALTHY PLANT GROWTH REQUIRES MINERALS

* Both the trays contain a soil substitute which contains no minerals.

* Tray 1 has been given pure water.
  Tray 2 has been given water containing mineral salts.



1
Given pure water only



2
Given water and mineral salts

1. Describe the appearance of the plants in each tray.

Tray 1

Tray 2

2. Which plants look healthier?

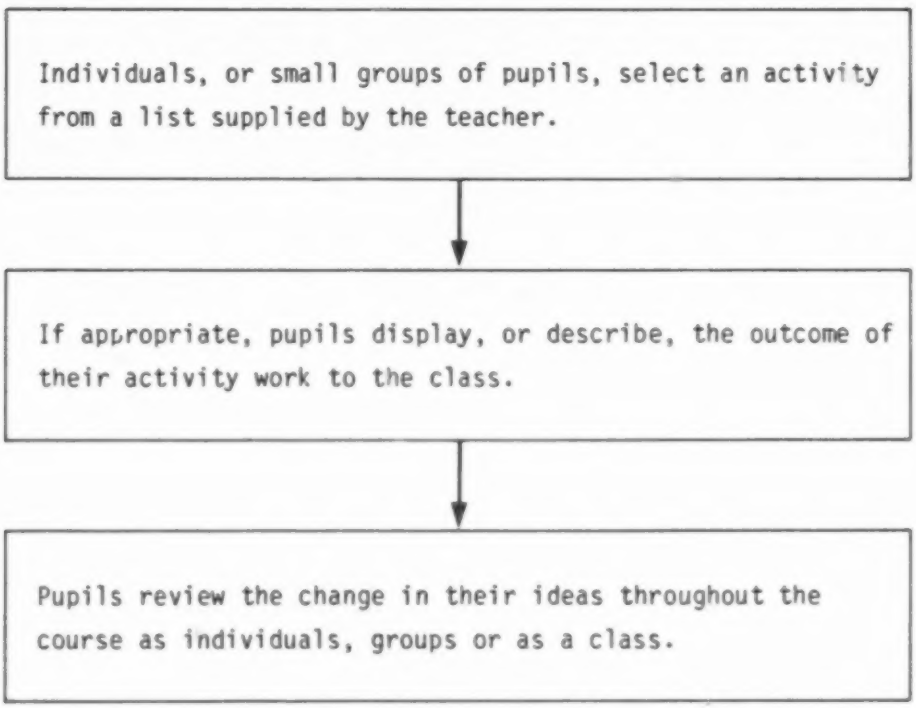
3. Mineral salts are required to make one group of foods. Name the group of foods.

4.4 Application and review of ideas: lesson 6

A list of activities is provided from which the teacher may select those most appropriate to the individual class. Each activity is intended to help pupils review their ideas and reinforce what they have learned by applying the ideas in novel situations. The activities themselves allow various approaches and products. They include using reference books, practical investigations, open-ended writing, model-making, poster production and are intended to allow an element of choice by the pupils for the most appropriate approach.

A review of the change in ideas throughout the course enables the pupils to become aware of what they have learned and also of what remains to be understood. Once more, a range of ideas for this activity has been provided, to enable teachers and pupils to select the most appropriate to their own needs.

TABLE 4.5 MATERIALS FOR APPLICATION AND REVIEW. OUTLINE OF LESSON 6.


Individuals, or small groups of pupils, select an activity from a list supplied by the teacher.
If appropriate, pupils display, or describe, the outcome of their activity work to the class.
Pupils review the change in their ideas throughout the course as individuals, groups or as a class.

Lesson 6

Focus	Lesson Activities		Equipment	Notes
	For the pupils:	**For the teacher:**		
Applying the scientific ideas to new contexts.	Individual or small group work on written or practical projects as selected.	Produce a list of activities from the suggestions given. Materials may need to be provided.	As required.	
Reviewing the change in ideas.	Individual or small group work on various activities as selected by the teacher.	Encourage pupils to be aware of any change in their ideas.	Posters from lessons 1 and 3, paper, pens.	

Lesson 6 Commentary

By the end of lesson 5 we hope that pupils will have become aware of, and developed some understanding, of the scientific view of plant nutrition as described in the 'pupil notes' and have had opportunities to use these ideas. For effective learning to occur we have provided some activities which give pupils opportunities to explore their understanding in a variety of novel situations.

This series of activities is not intended as a 'test' of their understanding, and pupils are encouraged to refer to their notes and to reference books where appropriate. The activities may be performed as individual or group exercises. We found it useful to make an initial selection from the attached list, but to allow the pupils to make the final choice depending on their own interests. This was found to increase the pupils' involvement with the activity. It should be pointed out that each exercise is open-ended and that there is a range of appropriate answers to each task. The pupils conducting practical activities were keen to publicise their work by producing a display, model or poster for the rest of the class. Model-making was not an 'easy' option but was successful in arousing interest. A group that had observed leaf cells from a moss plant had a heated discussion on the most appropriate colour of plasticine to use for the cell walls, cytoplasm and chloroplasts. They finally decided to make each cell from a sheet of green plasticine, and added white dots to represent the chloroplasts, rather than 'seeing' green chloroplasts suspended in colourless cytoplasm (see figure 4.6).

Some teacher advice may also be necessary to help pupils focus on plant nutrition. A project on devising methods of providing more food for Ethiopian victims of starvation concentrated on irrigation techniques rather than growing crops (see figure 4.7).

Towards the end of the lesson, opportunities should be provided for groups to familiarise themselves with each others' activities. If time allows, you may like to extend this lesson over a second week as it is both successful and rewarding.

PROJECT ON MOSS LEAVES

There were several categories for us to chose, my group and I chose "Where is chlorophyll found in the leaves of a moss plant?"

Method From the same moss plant we put two leaves under a microscope and observed them.

Results

We observed both leaves and found that the cells were different.

NEW ONE	OLD ONE
A	B

Obviously A is the new one for most cells are green therefore containing more chlorophyll so more food will be made in turn proves that it needs more food so predominantly growing rapidly like a young healthy bag should.

The old one B is almost transparent, some you can even see the nucleus!

Less chlorophyll is needed in an old plant for they don't grow as fast as a young one so they don't need as much food.

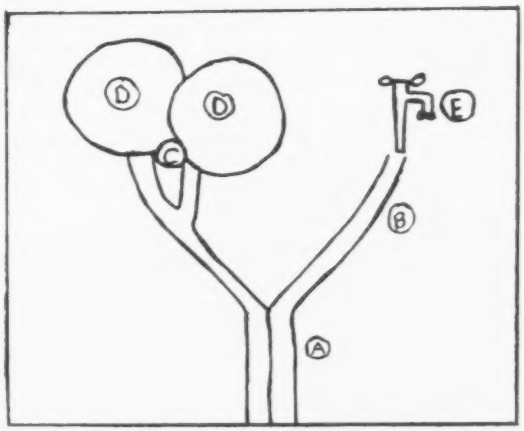
But most defiantly both A and B have that green line running down them.

Conclusion In a new bag the chlorophyll is found in most cells and in a line down the middle. In an old bag it is found around the cells

Figure 4.6 A group project on the distribution of chlorophyll in moss leaves

The live Aid Project.

At school in Biology we were given a choice of six projects to do. We chose the live aid project. The project was to design a schedule to use the money raised in a profitable way we designed a model.



Ⓐ = Main pipe.
Ⓑ = Seondry pipe leading to a wall
Ⓒ = Secondry pipe B leading to fields
Ⓓ = fields being irrigated to provide ~~water~~ food during the future
Ⓔ = tap to provide ready water for people.

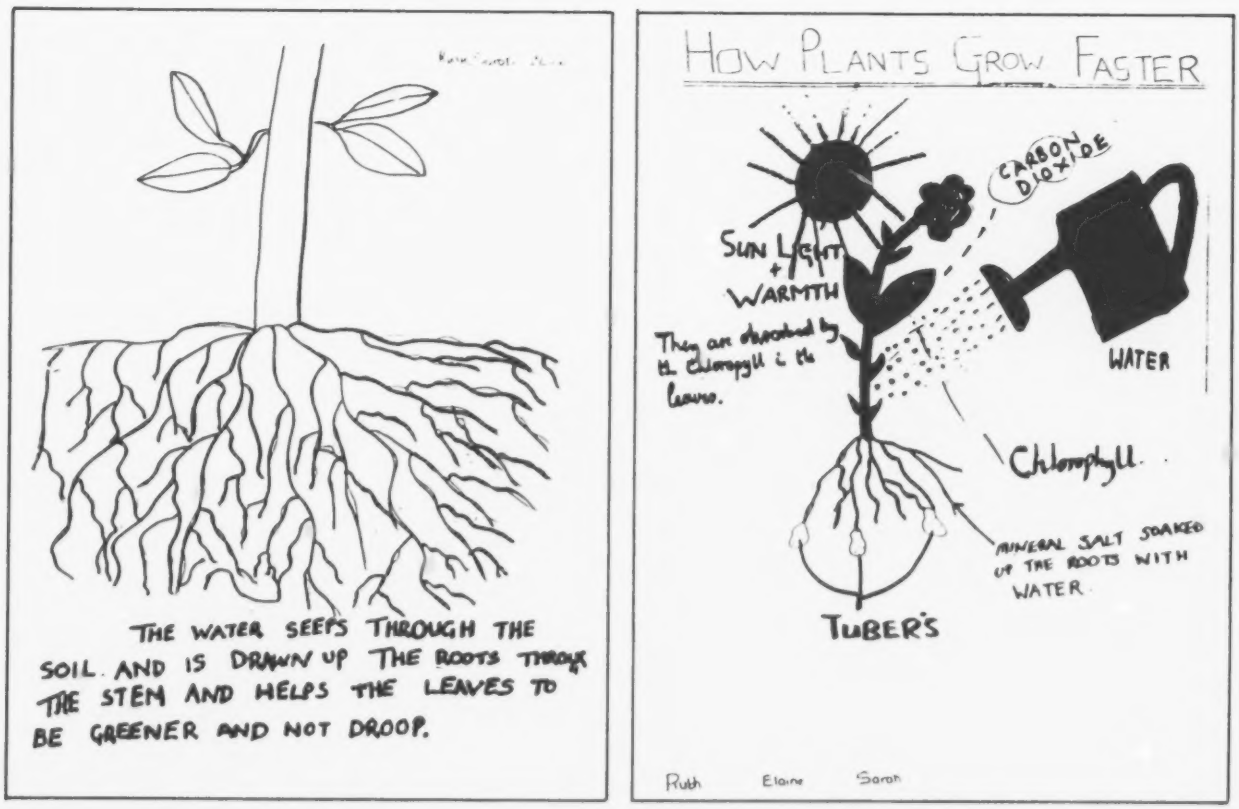
The land would be fertilized by water to help germinate the crops. As the sun is intense the plants would be able to perform a lot of photosynthesis. This would enable them to make a percentage of their own food.

Figure 4.7 A group project on the effective use of money for famine relief

Finally, the pupils are asked to review the change in their thinking throughout the duration of the plant nutrition course. Some strategies for this activity are:

- class or group 'marking' and correcting of their posters from lesson 1
- producing a second poster of their ideas on "How do plants get their food?" and comparing this with the first (see figure 4.8)
- producing some materials that would explain how plants get their food to younger pupils.

An example of an application activity, that engaged a group of pupils long after the lesson had ended, is shown in figure 4.9 (this is a sample of some of the pages taken from the booklet that they typed themselves).


THE WATER SEEPS THROUGH THE SOIL AND IS DRAWN UP THE ROOTS THROUGH THE STEM AND HELPS THE LEAVES TO BE GREENER AND NOT DROOP.
HOW PLANTS GROW FASTER
CARBON DIOXIDE
SUN LIGHT + WARMTH
WATER
Chlorophyll
MINERAL SALT SOAKED UP THE ROOTS WITH WATER
TUBERS
Ruth
Elaine
Sarah

Lesson 1 Lesson 6

Figure 4.8 Posters produced by one group of pupils during lesson 1 and at the end of lesson 6 to review the change in their ideas about plant feeding

Then Collin came up with another idea that of using a bean. The soya bean is an example of a commonly used protein source. It is very vresatile and as can be seen by a trip down to the super market, it is already being used and becoming increasing popular in the form of "BEANFEASTS" However as no foods contain everything a person needs to survive it seems unlikrly that the astronauts could maintained healthily in space for over the three weeks. So it looks like the astronauts will be having tube for a long while. However I believe that in this project we are maant to be showing how to keep the plants alive and healthy in this alien environment.

The Aparatus

I have decided in space too many things go wrong therefore this life support system MUST be easy to maintain and have a backup system. Therefore simplicity is the main factor.

Here I will list all the things the plant needs to survive :-

LIGHT, WATER, MINERAL SALTS, AN AIR(O &CO_2)

LIGHT

On the sheet it says-"their energy supply is LIGHT usually from the sun." Therefore the light can be artificial.

WATER

Unfortunately there is only one real way to have this, you can't make it. I would have a computer various places. These would sense if the water was not in sufficent amounts in the "SOIL". If there wasn't an artificial sprinkler above that place would be activated (of course artificial gravity would be needed).

MINERAL SALTS

The mineral salts could be administed in the water supply. This could be premixed on Earth.

AIR

This air need not be like our own. All the plant needs is oxygen and carbon dioxide. Therefore a 50-50 mixture might be usful. The plant should keep it balanced. There is a chance that some of the air may escape when the astronauts get their food. Therefore a computer could check and correct any imbalance.

"SOIL"

This is simply sand (its easier to plant something in sand than water).

GRAVITY

This could be induced by spinning. SEE DIAGRAM. NOTE: makes one revolution per 3 mins. (equal to the gravity on Earth at 128feet from the axis.)

nNIGHT&DAY

The plants must rest sometime. Therefore the light will be on for 13hrs., 11hrs. off.

Figure 4.9 An extract from a group's response to an application activity which asked them to design a life-support system for Skylab

List of suggestions for application activities

Here is a list of suggested activities for lesson 6. It includes practicals, model-making and a selection of questions which could be discussed or answered in written form. It is important that some element of pupil choice should be exercised. It may be necessary for the teacher to focus the pupils' attention on the plant nutrition aspects of each activity.

1. Observe stomata using nail varnish or superglue, and a microscope.

2. Make a model of a section through a leaf either by imagining or using text. Suggested materials include: cling film, plasticine, balloon, felts, string, plastic bottles.

3. Make a model to show how carbon dioxide and water are synthesised into sugar.

4. Design a poster to show the main parts of a plant and the jobs they do. Make it large, clear and attractive and suitable for a nine year-old to understand. Try it out. How would you change it?
   Now design another poster but this time suitable for a science teacher to understand. Try this one out and change it if necessary.

5. Using a microscope find out which parts of a moss leaf contain chlorophyll. Produce a poster or a plasticine model to show what you found.

6. Van Helmont in Nuffield Biology Text 2.
   (a) Read about Van Helmont's experiment.
   (b) Describe, as if talking to an 11 year-old, how Van Helmont explained his observations.

7. Chlorophyll is essential, even to meat-eating animals like lions. Discuss.

8. How would you improve the yield of some tomatoes by controlling their growing conditions? What would you do to a) light,
   b) carbon dioxide,
   c) heat,
   d) anything else needed?

9. People often say that plants get their food from the soil. Do you agree with this or not? Explain carefully what you think, paying special attention to what you mean by food.

10. Plant nutrition (feeding) is different to animal nutrition. Think of five differences.

11. Suppose you are provided with the following meal: potatoes, carrots, beef and milk. If you are given this meal you would get energy from it and this energy could then be used by you to move and grow. Explain how this energy may be linked with energy from the sun.

12. Burning magnesium in air to form magnesium oxide is an example of a chemical reaction called synthesis (synthesis means building up). The way green plants make carbohydrate/sugar/food is another example of synthesis. Give three similarities and three differences between these two reactions.

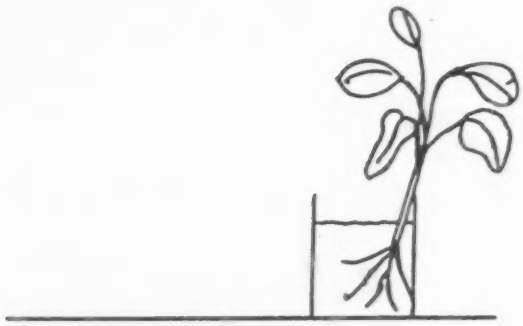
13. Imagine you are an atom of hydrogen. You start off your day as part of a molecule of water in the soil, but by midnight you have become part of a starch molecule in a bud.
    a) Describe what you look like as an atom of hydrogen.
    b) What does it feel like?
    c) Explain what happens to you
        i) in the soil
        ii) from the soil to a leaf
        iii) in a leaf
        iv) from a leaf to a bud
        v) in a bud.

    (If you are moving, how? Where do you pass through? Who are you with?)

14. Open ended questions. Examples of these are shown on the following sheets headed 'Brenda' and 'Villain'. These questions may be answered individually and the responses discussed as a class, or they may be answered jointly by small groups of pupils.

'Brenda'

Brenda learnt in a science lesson that plants need food.



She had a living plant in a jar of water on the windowsill at home for the last month and she wondered how that plant gets its food.

How would you explain this to Brenda?

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'Villain'

In a science fiction book, a villain threatens to spray the countryside with a chemical that destroys chlorophyll (the green substance in plants). The villain knew that if he destroyed the chlorophyll the plants would die.

Why would the plants die if the chlorophyll was destroyed?

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'Brenda'

The plant will go make its food from the water that she gives it and the sunlight from the sun

The plant takes in light through its leaves it also takes in water through its roots and carbon dioxide through its stomata. it then use the light to turn the orther two substances into food a by product is oxygen

'Villain'

Because without Chlorophyll the plants can't turn the light energy into food. With no food they ~~can't~~ haven't got any form of energy so they can't do anything.
If there was no chlorophyll, there would be no food made so the plants would die.

If the chlorophy was destroyed the plants would not be able to make starch and there would be no food made

5 Some reactions to the teaching scheme

During the evaluation of the teaching scheme many comments and opinions were gathered. The selection below gives some flavour of both pupils' and teachers' reactions to the materials.

5.1 From pupils

The following comments are pupils' written responses to individual lessons and also to the scheme as a whole.

1. What do you think about:

   a) posters?

> a good way of simplifyig hard to understand things
>
> "a good way of simplifyig hard to understand things."

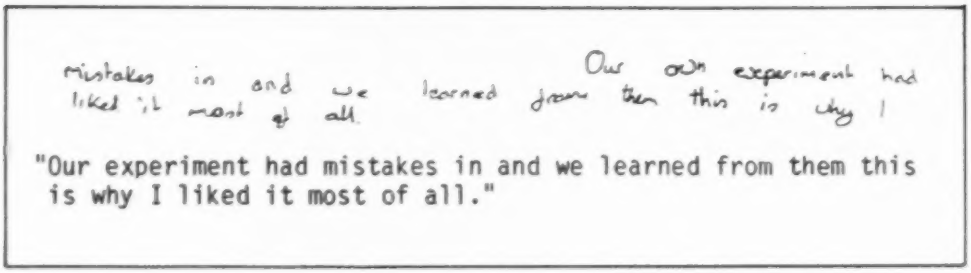
   b) discussion?

> DISCUSSING AS ONE LARGE GROUP, IT HELPED ME HAVE DIFFERENT IDEAS
>
> "discussing as one large group, it helped me have different ideas."

> More of: group experiments and disscussion in small groups
> Less of: describing what you did in front of the whole clas
>
> "More of: group experiments and disscussion in small groups.
> Less of: describing what you did in front of the whole clas."

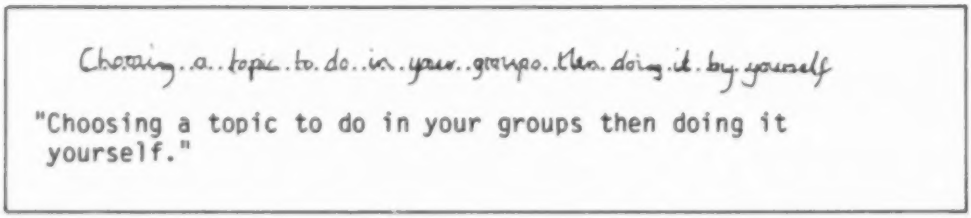
Generally, discussion was seen as a valuable activity in science lessons, with most positive comments mentioning the value of hearing other people's opinions. A significant proportion of pupils mentioned how awkward they felt when it was their turn to report their group's opinions to the class.

c) designing your own experiment?



"Our experiment had mistakes in and we learned from them this is why I liked it most of all."

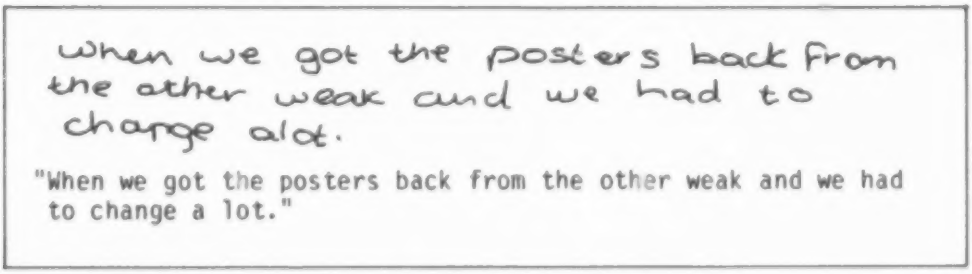
2. What was the most important part of the scheme for you?



"Choosing a topic to do in your groups then doing it yourself."

A large number of comments mentioned the importance of being given a choice of activity in lessons. Other activities mentioned as being important included doing their own experiment and discussion.

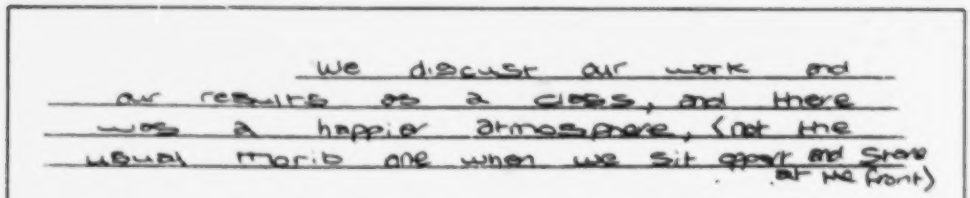
3. Which part of the scheme made you change your ideas?



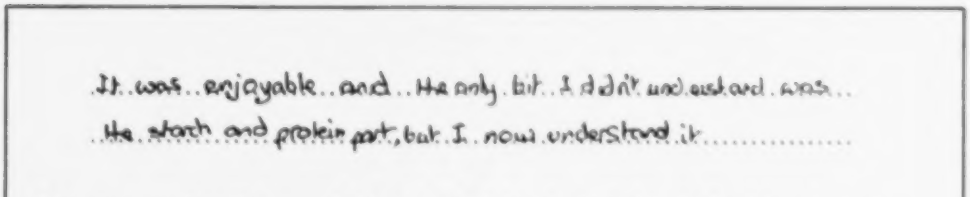
"When we got the posters back from the other weak and we had to change a lot."

This comment was not altogether typical, but reveals the children's perceived importance of reviewing their own thinking.

4. Would you like to say anything else?



"We discust our work and our results as a class, and there was a happier atmosphere (not the usual morib one when we sit appart and stare at the front)."



"It was enjoyable and the only bit I didn't understand was the starch and protein part, but I now understand it."

As the scheme was trialled, we became concerned that there may develop in our pupils a feeling of having been cheated. This could have arisen as a result of spending three lessons probing pupils' ideas and then changing direction in the fourth lesson by introducing the school science view.

With this concern in mind, a researcher (R) interviewed a small group of pupils (S1, S2, S3) at the end of their lessons on plant nutrition. An extract of their conversation is transcribed below.

R ... you were asked what your own ideas were to begin with and then you were told the scientists' ideas, was it important to be asked about your own ideas first?

S_1 Yes .... because, well ..

S_2 Well, there's not much point in learning something if you already know it, so that could patch in what you don't know and things like that.

S_1 It's good to be able to put your own theory forward first ...

S_3 If you've got any theories to start with, it makes you think..

5.2 From teachers

Teachers in the working group felt that they had made significant changes in the way they viewed teaching, and in their classroom practice whilst involved with the project. Some of their written comments on using the plant nutrition scheme are included to give a flavour of their thinking.

"Most of the pupils enjoyed the work, especially the idea of suggesting hypotheses and testing them experimentally. There was less reluctance to discuss and present ideas than I had expected, and the discussion was at a serious and considered level."

"Often I felt in the classroom situation personal goals were not necessarily set by pupils unless a number of statements or ideas which the pupils had formulated were listed or highlighted as important ideas to test. This testing of statements/ideas in the class exercise using posters, in the reporting back session, required a varying degree of teacher 'prompting'."

"I found it refreshing that so many children were enthusiastic about being given the opportunity to express their own ideas and to test them."

When commenting on lessons 4 and 5:

"Whereas, I thought, that pupils would have responded more positively to the presented scientific ideas and demonstrations in a didactically orientated scheme, they seemed to be 'switched off' to some extent when such a presentation was offered after their initial taste of 'conceptual freedom'."

"1. The children enjoyed the course on the whole, even those who at first lacked confidence. A 'low ability' child, for example, said that it was better now that I did not tell them everything they must do.
2. Surprisingly there was a decrease in teacher/pupil conflicts, given the freedom of the situation, which must be due to increased teacher/individual pupil contacts.

3. The children became more independent and innovative as time moved on, with the lower ability children coping as well, if not better, than the more able children. The children; some of them, gave up part of their free time to continue their work."

"The scheme greatly motivated the pupils. They were very keen to come to the lessons - move the benches into "group positions" and get on with the work in hand - particularly if it was their own practical work. The pupils enjoyed the fact that their own ideas were valued and that they were given the opportunity to test those ideas experimentally. (It is important to give help with experimental design here. It is now written into the scheme that it is the pupil's idea which is of primary importance and as much help as necessary should be given for that idea to be tested successfully.)"

"I am glad that I had the opportunity to take part in the teaching of the scheme.
The experience enabled me to be aware of how little I know about children's learning, and to reflect on my own teaching methods.
The positive outcomes ..... which have continued to influence my teaching are:

* the importance of discovering pupils' ideas about a topic
* the value of using group discussions and reporting back sessions
* the development of my own skills in managing these activities."

"I was dissatisfied with the experience of teaching plant nutrition using the Nuffield approach and materials. After teaching our scheme through once I feel to be at the start of a learning course with the promise of a more effective way of teaching this and other demanding topics at the end.
Although the main aim is greater conceptual understanding, the incidental advantages are quite marked. Plant biology in general is not popular with third year pupils but my pupils enjoyed using this approach. This is probably due in part to the novelty value but I suspect the greater emphasis upon the pupils' own ideas and experiments will have a lasting effect on motivation.
There are difficulties to be overcome in the organisation of discussion and pupil-initiated practical work but these are no greater than with any change of teaching style."

5.3 Postscript

Feedback

We would be interested to hear the reactions of anyone who reads this teaching scheme, and also the reactions of teachers or pupils who have used the scheme in the classroom.

We would hope that teachers would be prepared to modify these materials for use with particular groups of pupils, or for different areas of scientific content. Again, feedback would be gratefully received.

Please address your comments to:

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Centre for Studies in Science and Mathematics Education
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Helpline

Please contact the above address if you would like advice on using any of the materials in this scheme, or for information about other CLISP materials.

Notes and References

1. The reader may find the following research on children's ideas to be of interest:
   Bell, B.F. and Brook, A. (1984) Aspects of Secondary Students' Understanding of Plant Nutrition. Children's Learning in Science Project, University of Leeds.
   Simpson, M. and Arnold, B. (1982) Availability of pre-requisite concepts for learning biology at certificate level. Journal of Biological Education, 16, 1, 65-72
   Smith, E.L. and Anderson, C.W. (1984) Plants as Producers: a case study of elementary science teaching. Journal of Research in Science Teaching, 21, 7, 685-698

2. See, for example, Bell, B. in collaboration with Barron, J. and Stephenson, E. (1985) The construction of meaning and conceptual change in classroom settings: Case studies on plant nutrition. Children's Learning in Science Project, University of Leeds.

3. A more detailed description of the rationale behind the development of the schemes is given in Driver, R. and Oldham, V. (1986) A constructivist approach to curriculum development in science. Studies in Science Education, 13, 105-122

4. Oldham, V. (1987) A constructivist approach to teaching plant nutrition: a report on the scheme in action. The Children's Learning in Science Project, University of Leeds.

5. For a description of the perspective on learning adopted by the project, see the teacher booklet: Scott, P. in association with Dyson, T. and Gater, S. (1987) CLIS in the Classroom: A constructivist view of learning and teaching in science. Children's Learning in Science Project, University of Leeds.

6. Needham, R. in association with Hill, P. (1987) CLIS in the Classroom: Teaching strategies for developing understanding in science. Children's Learning in Science Project, University of Leeds.

Further reading

On views of learning:

Osborne, R. and Freyberg, P. (1985) Learning in Science. The Implications of Children's Science. Heinemann. Auckland, New Zealand.

Bentley, D. and Watts, M. (1984) Some Ideas of Learning in the Area of Science Education. A workshop pack. Secondary Science Curriculum Review.

Driver, R. (1983) The Pupil as Scientist? Open University Press, Milton Keynes.

On children's ideas:

Children's Learning in Science Project full reports: Aspects of Secondary Students' Understanding of: Particulate Nature of Matter (1984), Heat (1984), Plant Nutrition (1984), Energy (1984), Elementary Chemistry (1986). University of Leeds.

Driver, R., Guesne, E. and Tiberghien, A. (1986) Children's Ideas in Science. Open University Press, Milton Keynes.